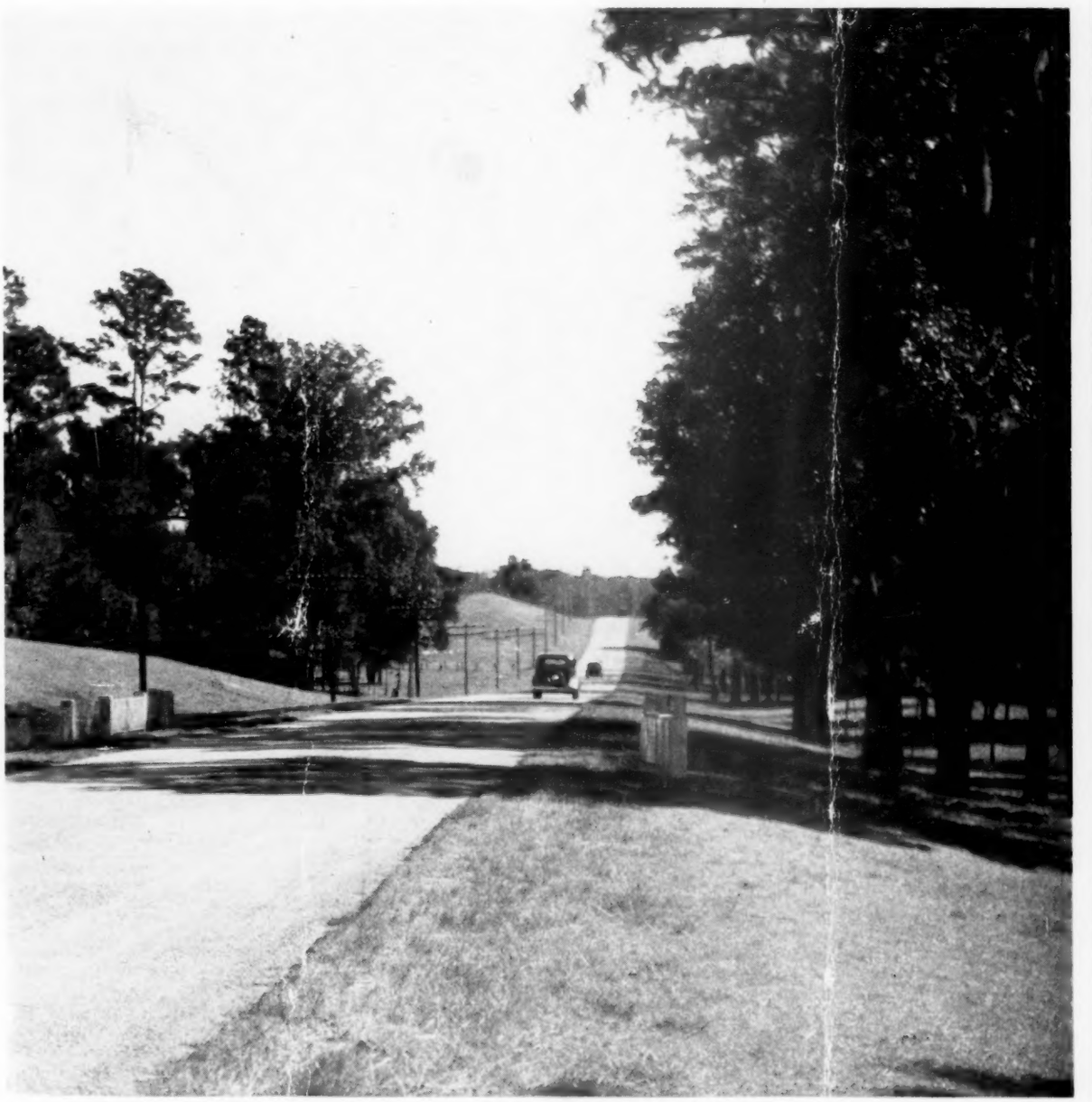
PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

FEDERAL WORKS AGENCY
PUBLIC ROADS ADMINISTRATION

VOL. 23, NO. 1 ▽ MARCH 1942



WELL-DESIGNED DRAINAGE CHANNELS ALONG U S 90 IN FLORIDA

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PUBLIC ROADS ▸▸▸ *A Journal of Highway Research*

issued by the

FEDERAL WORKS AGENCY
PUBLIC ROADS ADMINISTRATION

D. M. BEACH, *Editor*

Volume 23, No. 1 March 1942

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THE DESIGN OF ROADSIDE DRAINAGE CHANNELS

BY DISTRICT 10, PUBLIC ROADS ADMINISTRATION

Reported by CARL F. IZZARD, Associate Highway Engineer

Good surface drainage is an important element in the safe, convenient, and economical use of a highway. This report presents a procedure for analyzing drainage problems and designing channels to avoid future difficulty and abnormal expense in maintaining the surface drainage system. This procedure consists of first estimating the peak rate of runoff from each drainage area contributing to channels along the highway; second, checking the ability of these channels to carry the estimated discharge without eroding or overflowing; and third, designing protection against erosion or designing modified channel sections for increased capacity where necessary.

This discussion is limited to consideration of the problem in humid sections of the country where sod can be readily established. The "thatching" action of sod in protecting the soil from erosion increases manyfold the depth of water that may be satisfactorily carried in a channel and also increases the maximum gradient permissible for such a channel. The cost of providing sod is usually substantially less than the cost of paved gutters, the design of which is also discussed.

THE SCOPE of this study is the design of roadside drainage channels with respect to erosion control, adequate capacity for normal peak rates of runoff, landscape considerations, efficient maintenance, ultimate economy, and traffic safety. Because climatic conditions greatly affect methods that may be successfully employed for erosion control, the scope is limited geographically to the humid regions where rainfall is sufficient in amount and seasonal distribution to support native grasses forming a good sod.

The primary purpose of the roadside drainage channel is to provide for efficient removal of surface runoff from the roadway so that traffic can move safely and cars can park clear of the paved roadway in rainy weather when necessary. The channel, therefore, should have adequate capacity to carry the normal peak rate of runoff without overflowing onto the road shoulders. For ultimate economy, the channel should retain this capacity during the life of the road without excessive maintenance costs; this means that the channel should not erode or silt up. In the snow belt, the channel may be designed for snow storage. Since safety is of paramount importance in highway design, the drainage channel should have gently sloping sides and a slightly rounded bottom (see the cover illustration) so that a vehicle forced off the roadway can run down into the channel without overturning. In hilly or mountainous country, practical considerations of economy in first cost will limit the extent to which this ideal cross section may be attained. Prevailing standards of right-of-way width should not be permitted to restrict the width of channel necessary for hydraulic capacity or traffic safety.

The modern highway cross sections in use in most of the State highway departments are in accord with these design principles in varying degrees. The emphasis on traffic safety together with the increasing appreciation of good landscape design has resulted in widespread acceptance of the wide, shallow roadside drainage channel in place of the deep, narrow ditch carried over from railroad design. The practice of seeding or otherwise artificially establishing sod on shoulders, slopes, and drainage channels where feasible has developed as the necessity for controlling erosion became apparent. The principal object of this study is to present a simple method of determining in advance of construction the portions of drainage channels that are likely to erode unless treatment other than ordinary seeding is provided.

EROSION HAZARD IN DRAINAGE CHANNELS DETERMINED

Control of erosion is fundamentally a matter of controlling the velocity of surface flow or of treating the material so that it will withstand the velocity likely to occur. The velocity at which water will flow in a given channel depends on the interrelated factors of grade, shape of cross section, roughness of channel lining, and the rate at which water is delivered to the channel. Figure 1 is a simple diagram which takes all these factors into consideration.

This diagram is to be used for investigating the erosion hazard in the typical roadside channel and is applicable only to the cross section for which it is computed. Since simplicity in design and construction requires the use of a standardized cross section as much as possible this limitation is not a serious drawback, particularly since similar diagrams for other shapes of channel commonly used can be readily prepared. Figures 2 and 3 are diagrams for two other cross sections. The curves are computed by the Manning formula (see table 1).

TABLE 1.—*Channel roughness for use in selecting scales on velocity–discharge diagram* [1]

Type of lining	Scale	Value [2] of n
Ordinary earth, smoothly graded	Smooth	0.02
Jagged rock, or rough rubble	Rough	.04
Rough concrete	Smooth	.02
Smooth rubble	do	.02
Well-maintained grass, depth of flow over 6 inches	Rough	.04
Well-maintained grass, depth of flow under 6 inches	Very rough	.06
Heavy grass	do	.06

[1] In general, use roughest condition likely to exist for estimating capacity, and smoothest condition for estimating velocity.
[2] In the Manning formula.

The use of the diagram may be illustrated as follows: Assume that peak rate of run off has been estimated at 10 cubic feet per second for a channel having the cross section shown in the diagram and a grade of 4 percent. To check the velocity on bare earth, use the "smooth" scale ($n=0.02$); move along the curve for 4 percent grade to point "a" where discharge equals 10 cubic feet per second and read 6.8 feet per second on velocity scale. This velocity is excessive for earth (see table 2) so it is concluded that sodding is necessary. With sod

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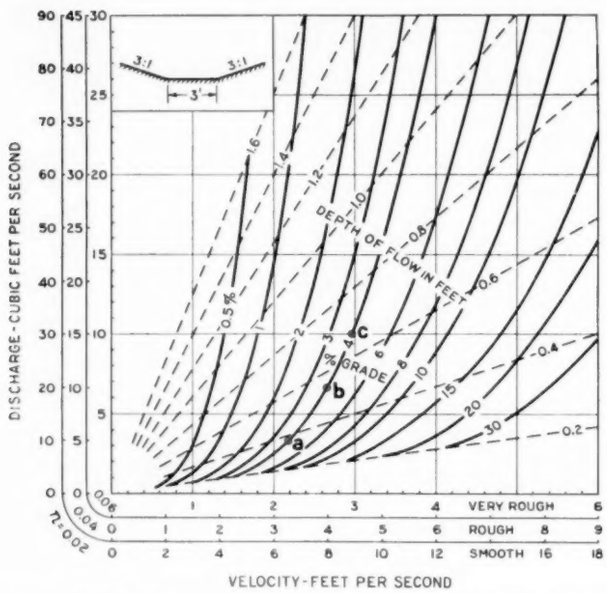

FIGURE 1.—RELATIONS BETWEEN GRADE, DEPTH, DISCHARGE, AND VELOCITY FOR A CHANNEL 3 FEET WIDE AT THE BOTTOM AND HAVING 3:1 SIDE SLOPES, FOR VARIOUS LININGS.

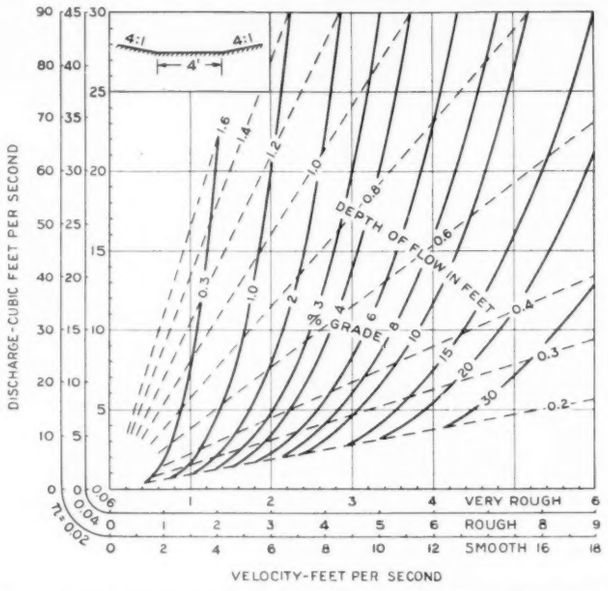

FIGURE 2.—RELATIONS BETWEEN GRADE, DEPTH, DISCHARGE, AND VELOCITY FOR A CHANNEL 4 FEET WIDE AT THE BOTTOM AND HAVING 4:1 SIDE SLOPES, FOR VARIOUS LININGS.

use the "rough" scale ($n=0.04$); from the curve for 4 percent grade at "b" read velocity equal to 4 feet per second. This velocity is allowable for good sod.

TABLE 2.—*Allowable velocities in various channels*

Type of lining	Allowable velocity
	Feet per second
Well-established grass on any good soil: [1]	
Bermuda grass	6
Bluegrass	5
Smooth brome grass	5
Western wheat grass	4
Buffalo grass	4
Sudan grass (annual, temporary cover)	3
Common lespedeza (annual, reseeding)	3
Lespedeza sericea	3
Earth without vegetation: [2]	
Fine sand or silt, noncolloidal	1–2
Ordinary firm loam	2–3
Stiff clay, very colloidal	4
Clay and gravel	4
Coarse gravel	4
Shale	5

[1] Data from Roadside Development Report, Part II, Appendix IV, April 1940.
[2] Data adapted from recommendations of Special Committee on Irrigation Research, American Society of Civil Engineers 1926.

If grasses are allowed to grow rank the resistance to flow is increased and the velocity is still further decreased. Since a decrease in velocity must result in an increase in cross-sectional area of flow if the given peak rate of discharge is to be obtained, the channel may be overflowed. To check on this condition the depth of flow should be investigated as follows:

Dotted lines are drawn through points of equal depth of flow on the discharge curves. Thus in the preceding example water would flow about 0.4 foot deep in a bare earth channel (point "a"), or about 0.55 foot deep in the sodded channel (point "b"). If the grasses are allowed to grow rank the flow will be approximately as shown on "very rough" scale ($n=0.06$), point "c," which lies about one-third of the distance from the 0.6 to the 0.8 foot depth. The depth of flow is thus approximately 0.67 foot with rank grasses. This illustrates why the required depth of a channel should be based on the roughest condition of the channel likely to exist. A freeboard of at least 0.3 foot should be provided above this maximum depth of flow to allow for silting, for wave action, and for a factor of safety against too low an estimate of peak runoff.

In channels with comparatively flat side slopes the discharge capacity increases rapidly with small increases in depth, and consequently the allowance of 0.3 foot freeboard is usually adequate. In the example, the discharge capacity at a depth of 1.0 foot is more than double that at a depth of 0.67 foot. The resulting velocity is about 5.5 feet per second on the "rough scale" which is above the recommended limit for bluegrass sod, but since this limit is conservative, appreciable damage need be anticipated by a runoff double that for which the channel was designed. Silting in the bottom of the channel, while reducing the depth of flow, will reduce both the cross-sectional area and the discharge capacity only a small amount. For the same reason the rounding of the bottom of the channel usually shown on typical cross sections does not significantly affect the discharge capacity computed for a strictly trapezoidal section.

SEVERAL MEANS OF INCREASING CAPACITY

In any channel with fixed side slopes the discharge capacity may be increased by increasing (1) grade, (2) bottom width, (3) depth, or through decreasing resistance to flow by providing a smoother lining. Increasing the grade is frequently impractical. Increasing the bottom width has the least effect on velocity and is therefore desirable where velocity is close to the limit. On the other hand, increasing the depth, while increasing velocity slightly more than that with increased bottom width, is the simplest procedure and also requires less over-all width. The latter consideration is important where right-of-way is restricted or expensive. Smoothing of the channel lining provides increased capacity without increased width (or may even permit a reduction of width) but, since this must generally be accomplished by some kind of paving, the cost may become excessive.

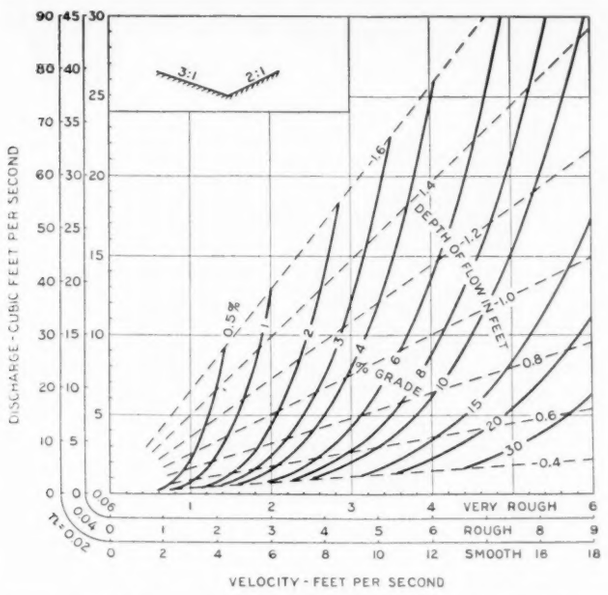

FIGURE 3.—RELATIONS BETWEEN GRADE, DEPTH, DISCHARGE, AND VELOCITY FOR A V-SHAPED CHANNEL HAVING 3:1 AND 2:1 SIDE SLOPES, FOR VARIOUS LININGS.

The effect of channel cross section on depth of flow, velocity, and required width of channel is demonstrated in table 3, based on figures 1, 2, and 3. Note that the V-shaped channel has the greatest depth of flow and requires nearly as much width as the section with a 3-foot flat bottom. The difference between the discharge flowing full and 10 is the reserve capacity afforded by the 0.3-foot freeboard.

Instead of providing additional capacity in a given channel it is sometimes possible to divert part of the runoff into another channel as by the construction of an intercepting ditch on top of the cut slope. Treatment of the drainage area to increase infiltration, by mulching or other means, will also reduce the peak rate of runoff.

TABLE 3.—*Examples of effect of channel shape on capacity* [1]

	3-foot bottom 3 : 1 slopes	4-foot bottom 4 : 1 slopes	V-bottom 3 : 1 and 2 : 1 slopes
Depth of flow ..... feet..	0.95	0.80	1.45
Depth plus 0.3 foot freeboard ..... do....	1.25	1.10	1.75
Velocity ..... feet per second..	1.8	1.6	1.9
Width (including freeboard) ..... feet..	10.5	12.8	8.8
Discharge flowing full..cubic feet per second..	17	18	16

[1] Taken from figures 1, 2 and 3 with discharge of 10 cubic feet per second flowing in sodded channels on a 1-percent grade ($n=0.06$).

On grades of less than 2 percent the design of a sodded channel is likely to be determined by capacity requirements. As the grade is steepened the velocity increases and a point is reached beyond which the maximum allowable velocity becomes the determining factor. For a given rate of discharge and a fixed grade the velocity may be kept within reasonable limits by increasing the bottom width of the channel or by flattening the channel slopes. Both of these methods require a substantial increase in the overall width of the channel. Where it is not feasible to design a sodded channel, it may be paved; velocity is then no longer the governing factor. The capacity of a channel of given shape and depth may be doubled by changing the lining from well-maintained sod to concrete or masonry, or tripled if the initial lining was a rank grass.

Outfall channels carrying water discharged from cut sections frequently involve steep grades which would cause excessive velocities to be developed in ditches of standard cross section. The solution of this problem is to pave the channel or to increase the bottom width. The required bottom width of a sodded channel may be approximated by the following formula

$$b_2=b_1\times\frac{S_2}{S_1}$$

in which b_2 is the required bottom width, b_1 is the width of the standard section, S_2 is the proposed grade and S_1 is the grade on the standard section at which the given discharge produces the maximum allowable velocity. Use of this rule eliminates the necessity of preparing diagrams similar to figures 1 and 2 for channels with increased bottom width.

For traffic safety, side slopes of a paved channel should be as flat as practicable in locations where vehicles might be forced to drive down into the channel. In other locations, as at the top of a cut slope, or the toe of a fill slope protected by guard rail, economy dictates the use of a more efficient hydraulic section. The most efficient section, a semicircle, is difficult to construct and a semihexagonal section is preferable. If high velocities are developed in paved channels, provision must be made for checking the velocity at the outlet unless the channel discharges into a pool of water of appreciable depth. Velocity may be checked by a wide apron with projections or baffle walls on the surface or by a low sill at the end, creating a stilling pool. Current research on this problem, which exists at culvert outlets also, should provide more definite principles for the design of energy-dissipating structures.

WIDE, SHALLOW CHANNELS DESIRABLE

The ideal roadside channel cross section to be built in earth adjacent to an earth or stabilized shoulder should have a slope from the shoulder of at least 4 : 1 (which is the steepest slope that permits a driver in the outside lane to see the entire length of the slope), a rounded bottom at least 4 feet wide, and a back slope not steeper than 4 : 1. The depth should vary from a minimum of about 1 foot below the edge of shoulder in regions of low rainfall intensities to a minimum of 1½ feet in the Southern and Gulf Coast States. Depths and widths should be increased to provide additional capacity where the runoff analysis indicates that peak runoff rates from the tributary drainage areas are of such magnitude that the water is likely to rise above an elevation 0.3 foot below the shoulder line. When the ideal cross section results in an excessive amount of excavation which cannot profitably be used for embankment construction (as in flattening embankment slopes), the width of the bottom may be reduced and the backslope steepened to not more than 2 : 1, provided the discharge capacity remains adequate. The slope from the shoulder may also be increased to a maximum steepness of 3 : 1. The resulting cross section, however, will have very limited capacity and may require closely spaced culverts or auxiliary channels (intercepting channels or storm sewers) to avoid overflowing onto the shoulder during times of peak runoff.

The ideal cross section is based first of all upon obtaining a channel that a vehicle can cross at any angle with

a reasonable chance of remaining upright. But this section is also favorable to establishing and maintaining a good sod (it is flat enough to mow mechanically), provides space for snow storage, and lessens the chances of snowdrifts accumulating (because the wind blows across without eddies). Finally, the gentle slopes covered with sod easily merge into the landscape. The spaciousness of the entire roadway cross section tends to relieve the tension of driving because the driver feels that he can safely drive off the pavement in an emergency. Any departure from this ideal cross section that tends to narrow the roadway is usually a compromise between safety and economy or expediency.

In solid rock cuts, the backslope will necessarily be very steep, approaching the vertical in the extreme case. In such instances the drainage channel may have a narrow, rounded, V-shaped cross section just large enough to carry the peak runoff without overflowing on the shoulder. Another design having considerable merit requires paving the entire shoulder and providing for drainage in a monolithic curb and gutter with closely spaced catch basins emptying accumulated drainage into cross culverts or into storm sewers. Such a design balances the cost of additional excavation in a wider cut against the cost of more expensive drainage facilities and at the same time affords a maximum of all-weather traffic safety. It is difficult to maintain narrow sodded shoulders between a paved gutter and the paved roadway; in such cases the shoulder should be stabilized and surface-treated.

Obviously, erosion is not a problem in roadside channels cut in solid rock. However, since it is seldom practical to finish the channel smoothly, it may be advisable to pave the channel with concrete or rubble masonry to permit sufficient velocity so that extra cross-sectional area is not needed for the required capacity. Furthermore, in rock cuts there is usually a continual accumulating of spalled rock, cinders or sand from ice treatment, and loosened earth, which will be more readily removed by water flowing in a smooth-lined channel than in a jagged, rock-lined channel.

DITCH CHECKS AND DROP STRUCTURES SOMETIMES USED

Another method of controlling velocity in channels is to flatten the grade and build a series of steps, with abrupt drops built out of concrete, stone, timber, or other suitable material constructed at each step. The channel between drops is designed for a non-eroding velocity at the peak discharge rate. The structures are designed to discharge through a weir notch, which may have the same shape as the channel above, but is more frequently a constriction in the channel. In order to prevent under-scour an apron with wingwalls must be provided below the drop. The spacing of the drop structures will depend on the general gradient of the channel, the intervening gradient, and the vertical drop at the structure.

If the channel between structures is designed for a non-eroding velocity of about 2 feet per second in bare earth the intervening gradient will be less than 0.5 percent and the number of structures per 100-foot station will be approximately equal to the general gradient in percent divided by the drop in feet at each structure. Thus on a 5 percent grade, structures having a 0.5 foot drop would be spaced 10 to the station. The cost per structure would depend on the material and the size of notch necessary for the peak discharge. Properly designed concrete structures will cost from $5 to $10 or more each, or on a 5 percent grade, from $50 to $100 or more per station. For the same cost per station it would be possible in most cases to construct a paved, continuous gutter 3 to 5 feet wide, or a continuous sodded gutter 9 feet wide, either of which should adequately carry the discharge. The cost per station for drop structures will be less for higher drops but safety considerations limit the height of drop in roadside channels.

Where sod is used to line the channel between drop structures the intervening grade may be increased to as much as 5 percent (determined by reference to a velocity–discharge diagram such as fig. 2) which in most cases eliminates the need for stepping the grade line.

One of the main objections to building drop structures in channels parallel and close to the roadway is the hazard to traffic. The structures also interfere with mowing operations and are always unsightly. In some soils they are difficult to maintain because washing out of the soil occurs below or around the structure. Drop structures are useful, however, in channels normally inaccessible to vehicles on the roadway, as where a channel drops off suddenly into a creek bed. In such cases the drop should be designed as an engineering structure with ample notch capacity and protection against scour at the downstream end.

Any method of designing a channel for a limited velocity and adequate capacity necessitates an estimate of the peak rate of discharge which the channel will be expected to carry. This factor is very important but has received relatively little attention. The grade of the channel is usually thought of as being the criterion upon which the occurrence of erosion must be based, but a glance at figure 1 shows that velocity, which is the principal factor causing erosion, changes rapidly with the rate of discharge, particularly for low flows, regardless of the grade.

RUNOFF ESTIMATED BY SEVERAL METHODS

The peak rate of runoff may be estimated by several methods: The Burkli–Ziegler and the so-called rational formulas, and runoff curves developed by the United States Department of Agriculture. The rational formula is preferred to the Burkli–Ziegler because the slope factor introduced in the latter is of questionable value. The slope should be considered in estimating the time of concentration used in the rational formula by making a rough approximation of the probable velocity in the channels through which the water flows from the most remote part of the drainage area. This may be accomplished with velocity–discharge diagrams, using an assumed discharge. The velocity of overland flow on grass, where flow is not concentrated in a defined channel, may be roughly approximated by the rule of thumb that "the velocity in feet per second is approximately equal to one-tenth the square root of the total fall in feet, provided the grade is not more than 20 percent."

The simplest method of estimating runoff, probably as reliable as any other, is the use of runoff curves of the type published by the Highway Research Board in April 1940, in Appendix IV of the Roadside Development Report, Part II. By selecting a curve representing the topographic, soil, vegetal cover, and surface storage characteristics of the drainage area, the peak rate of discharge may be read directly in cubic feet per second from the size of the area in acres.

(*Continued on p. 13.*)

LAND USE PLANNING IN RELATION TO HIGHWAYS

WITH SPECIFIC REFERENCE TO DELTA COUNTY, COLORADO

Reported by W. J. KELLER, Highway Engineer, District 3, Public Roads Administration

THE Colorado Agricultural Land-Use Planning Committee was organized on April 26, 1939. The original group consisted of 12 farmer-rancher members representing the 12 major types of farm areas in Colorado, and one representative from each of the following State and Federal agencies:

U. S. Agricultural Adjustment Administration.
U. S. Bureau of Agricultural Economics.
U. S. Farm Credit Administration.
U. S. Farm Security Administration.
Office of State Forester.
U. S. Public Roads Administration.
U. S. Soil Conservation Service.
State Extension Service.
State Experiment Station.
State Highway Department.
U. S. Forest Service.

Since organization, representatives have been added to the committee from the Taylor Grazing Service, the Fish and Wildlife Service, and the State Planning Commission.

The objectives of the planning program are to develop an agricultural land-use program in which will be correlated the suggestions and work of the farmers and ranchers, the State Agricultural Extension Service and Experiment Station, the Bureau of Agricultural Economics, and operating agencies of the Federal and State governments; and to produce a planning program in which all of the above-mentioned agencies can effectively contribute to agricultural adjustment, conservation, crop insurance, farm forestry, flood control, land retirement, rehabilitation, and water utilization.

Consideration is given to land-use and its relation to roads, schools and other community facilities, credits, marketing, public finance, land taxation, tenancy, and transportation.

As a part of the general program of land conservation and utilization, State and county committees have been appointed in every State to study the problems confronting them intimately. These committees are generally composed of local farmer members and members of the various State and Federal agencies concerned.

The Public Roads Administration has recognized the close relationship between the objectives of land use planning and the problems confronting highway administrators and is cooperating fully in the general program. Representatives attend all State meetings and many of the county meetings, acting in an advisory capacity on matters pertaining to roads, soil erosion, flood control, aerial photography, mapping, etc. The Public Roads Administration has been able to contribute substantially to the general program by furnishing maps and various statistical data compiled by the State-wide highway planning surveys.

Under the leadership of the State highway department and Public Roads Administration representatives in Colorado, local subcommittees have been appointed to study and report on the road improvement program that will best meet the requirements of the county. The Delta County report describes how this particular committee approached the problems and the results of the studies.

PERTINENT STATISTICS PRESENTED

The following material is presented in an effort to bring out the rather simple procedure adopted by the Delta County Planning Committee with the thought of helping other counties and communities interested in land-use and its application to highway planning.

Delta County is a rather mountainous county in the western part of Colorado, covering about 1,200 square miles. The following pertinent figures are of interest:

	Acres
Total area	768, 640
National forests	190, 032
Public domain	158, 611
Irrigated land	60, 280
Dry farming land	12, 423
Fruit land	5, 891
Grazing land	223, 513
Population (1940)	16, 470
Number of farms in county (1930)	1, 898
Total assessed valuation of all land and improvements (1939)	$6, 308, 380
Average annual precipitation——inches	8. 3

The 1939 county tax revenue was approximately $441,000 and this sum was used for the following governmental purposes:

State	$43, 000
County	153, 000
Municipal	38, 000
General school	30, 000
Special school	177, 000

The outstanding bonded indebtedness as of 1939 was $254,000 in school bonds, $368,000 in municipal general bonds, and $37,700 in special municipal bonds. Tax collections have been below the State level and were 75.79 percent for the year 1939.

Delta County has a road system of 836.8 miles which the latest inventory shows to be divided into the classifications shown in table 1. It will be noted that over 95 per cent of the total mileage is made up of unimproved, graded and drained, and gravel surfaced roads.

The 1939 county road and bridge fund account reveals the following receipts and disbursements:

Receipts:	
Property tax	$58, 878
Specific ownership tax	2, 223
Receipts from cities	4, 844
Motor fuel tax	28, 995
Motor vehicle tax	15, 246
Motor carrier tax	2, 556
U. S. Forest Service	2, 563
Reimbursed items (labor)	460
Miscellaneous	9
Subtotal	$115, 774
Carry-over balance 12/31/38	7, 483
Total	$123, 257

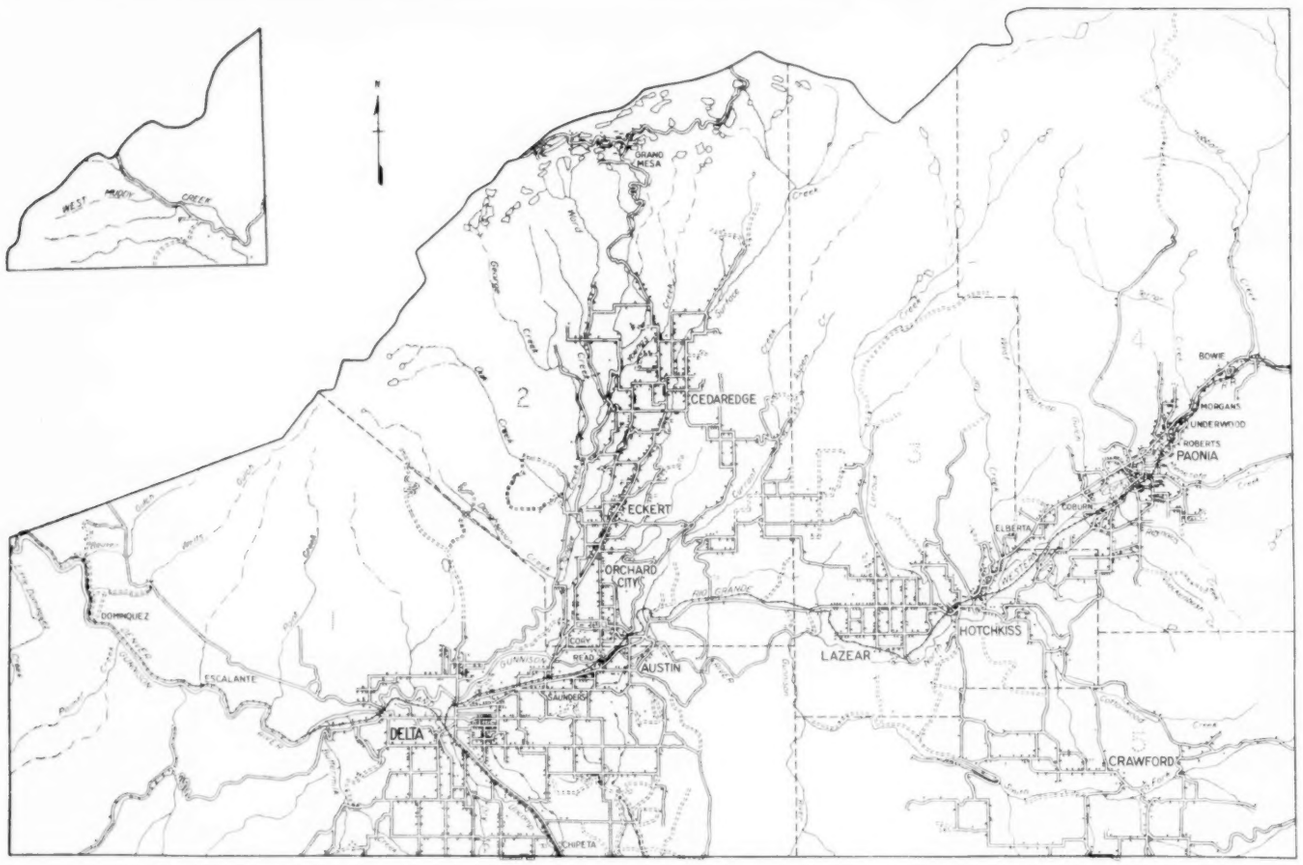

FIGURE 1.—CULTURAL FEATURES OF DELTA COUNTY AND BOUNDARIES OF COMMUNITY AREAS.

Disbursements:	
Construction, maintenance, and right-of-way	$87,955
Equipment	22,980
Fees to county treasurer	1,843
Transfers to other funds	6,959
Administration	841
Subtotal	$120,578
Carry-over balance 12/3139/	2,679
Total	$123,257

TABLE 1.—*Classification of rural roads in Delta County*

Type	Federal aid	State	County	Total
	Miles	*Miles*	*Miles*	*Miles*
Unimproved		9.3	450.7	460.0
Graded and drained		41.6	117.3	158.9
Gravel surfaced		76.3	105.0	181.3
Low-type bituminous	24.9	5.2	6.5	36.6
Total	24.9	132.4	679.5	836.8

In undertaking a county planning program, whether it be for highways or any other purpose, coordination is essential. An alert and interested county agent is a primary requirement. It is his job to undertake the correlation of material and do the necessary contact work. Delta County is fortunate in having such an agent, and the county agricultural committee has functioned efficiently in arousing enthusiasm and maintaining an interest in the several communities.

The first step in the highway planning program for Delta County was to obtain satisfactory large-scale maps. These were obtained from the Colorado Highway Planning Survey through the Bureau of Agricultural Economics at the State College. These maps display all cultural features such as a land grid system, all cities, towns, roads, and such details as State and national forests and parks, dwellings, schools, churches, buildings, and other traffic-generating points. Upon receipt of the maps the county was divided by the county agent into five community areas as indicated in figure 1. The map was then cut along the community boundaries and the respective map sections were numbered as shown in the figure. The first county highway meeting was called at this time. Chairmen were selected to represent each community group and given the map section covering their area of the county.

MAP SHOWING TYPES OF SOIL PREPARED FIRST

The chairmen were given instructions regarding the work to be done. They were informed that each community should first prepare a map showing types of soil. It was impressed upon the farmer-rancher members that technical soils studies and terminology were not desired, but rather that the farmers and ranchers should outline the areas according to classifications understandable to their own members. Upon completion of the five community soils maps, the county agent pieced them together again to form the county map. Necessarily, some adjustment was required at the community boundaries in order to make adjoining areas coincide. Surprising as it may seem, very little correction was required. The final result was figure 2.

The question arises—Why are highway people interested in a soils map? There are several reasons. The

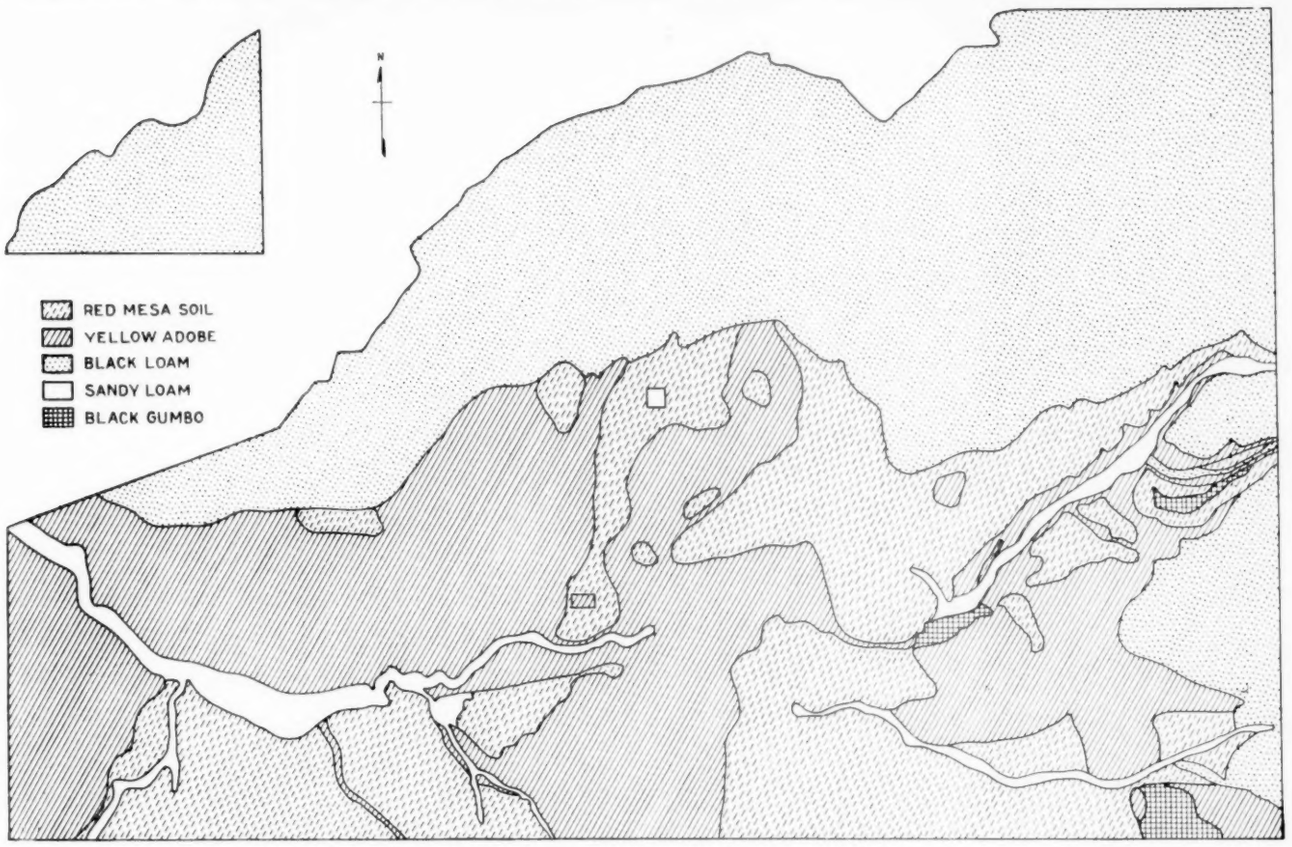

FIGURE 2.—TYPES OF SOIL IN DELTA COUNTY.

farmer and rancher know their own land; they know its capabilities and they are well qualified to state what lands are capable of production and what lands are unproductive or submarginal in character. The farmer or the rancher is far more capable of making this determination than is the highway engineer. In producing this Delta County map, the local people have shown graphically the areas of submarginal land which should not be opened to development and large-scale cultivation, thus expressing to the road builder the important fact that roadbuilding to any major degree must be discouraged in such areas. Some development may be necessary, but care must be exercised in the selection of such roads and their purpose carefully studied.

The soils map is a base for work by other agricultural agencies, for example, the Soil Conservation Service. The work being done in erosion control is well recognized, and in this map there are displayed those soils subject to erosion—those areas that are now problem areas in the county.

The next step comes under what is termed "land-use planning." The communities again were called upon to spot the actual land-use areas on their section of the map. Figure 3 shows the results of this study. Attention is directed to the grouping of existing units and how they follow the present road system. The public domain and grazing lands shown in figure 3 are not open for settlement and, except for areas within the national forests, probably represent rather unproductive lands of questionable agricultural value inasmuch as they have never been taken up in homestead. However, these areas are important to the Delta County range programs for livestock. The farming areas indicate portions of the county that require road facilities. The other sections are submarginal in character, requiring a minimum of road facilities. Normally, roads in submarginal areas are low in traffic volume and should be limited to those that are intercounty in character, those that provide small towns and communities with access to the main highways, or those confined to specific purposes, such as range management and supply.

Upon completion of the basic maps, the communities were requested to set up in their areas a road system which they felt would best serve their community needs. They were asked to ignore existing systems, to forget designated routes and present status of improvements. The thought was for the local people to discard personal prejudice and work toward an integrated road system that would provide service to the several towns and markets, to the churches, schools, social centers, and other gathering places.

The laying out of this road system by the communities immediately stimulated interest in this type of planning. Apparently everyone was concerned vitally with the highway system, especially in his community. The county agent was now called upon to do a lot of contact work. Coordination of routes, intercommunity in nature, had to be accomplished and, upon completion of the community plans, the routes had to be fitted into the complete county picture.

At this point a second county highway planning meeting was called, to which were invited representatives of each community, the county commissioners, the State highway department, the United States Forest

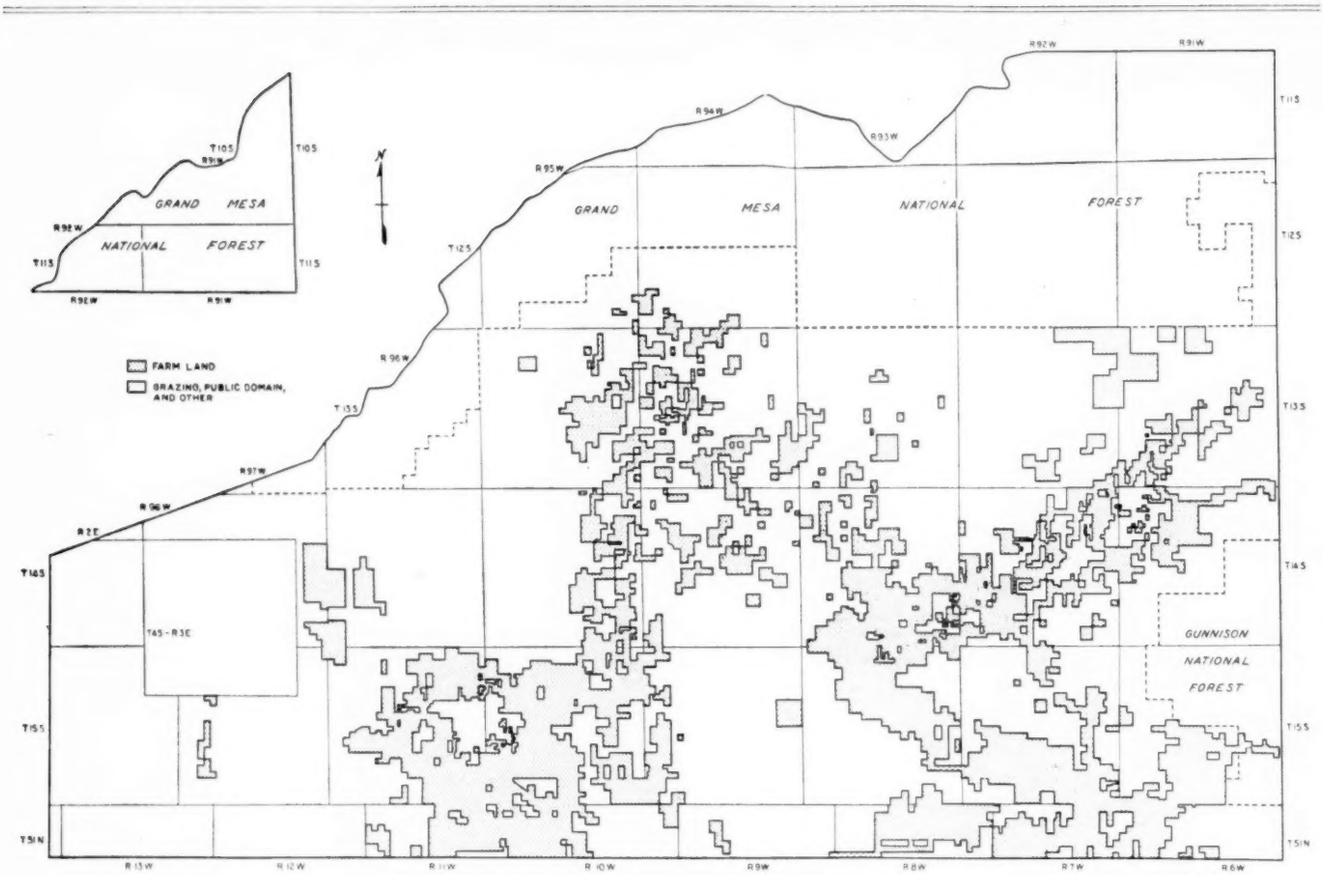

FIGURE 3.—PRESENT LAND USE OF DELTA COUNTY.

Service, and the Public Roads Administration. The county chairman explained the purpose of the meeting and requested each highway agency to indicate on the map which roads were eligible for improvement with funds from that particular agency.

ROADS OF INTEREST TO VARIOUS AGENCIES DESIGNATED

The Public Roads Administration representative indicated the Federal-aid system and those roads that were qualified Federal-aid secondary routes. The Forest Service representatives located the Forest highway system and those roads of interest to the Forest Service from the viewpoint of fire-fighting, truck trails, etc. (forest development system). In turn, the State highway department designated the State highway system. The remaining roads were the county system.

It was gratifying to note the interest displayed by the county road authorities at this meeting. Perhaps for the first time, they had been presented with factual data to substantiate the long-recognized difficult circumstances in which they find themselves in the task of providing adequate road facilities with available revenue. Factual data to aid in obtaining public support in any program that would remedy, or at least alleviate, the condition, are necessary if the problem is to be attacked successfully. The fact that such information was now available brought wholehearted support from the county commissioners.

Following this meeting, the community groups met to select a final plan which included the Federal-aid system, a series of routes designated as qualified Federal-aid secondary roads, the State highway system, and finally a county system. Figure 4 shows by appropriate symbols roads included in these several systems.

It is interesting to study roads that are requested to be abandoned and roads that are designated as a private obligation; also how the selected system fits into the soils-capability map. There are no roads into or through submarginal areas except the intercounty (Federal-aid) road running north and south, and the intercounty (Federal-aid secondary) road into the national forest. Several short stubs of county road are shown to extend into grazing and range lands for purposes of hauling stock and supplies.

Attention is directed to the mileage of "private road" serving but one or two ranches. In one instance, it was stated that several thousand dollars had been expended by the county to maintain a road serving but one ranch. Similar instances were found in other places from a study of county records.

Attention is also directed to the road marked for abandonment in the southwest part of the county. A considerable sum of county funds had been expended in gravelling this road. Subsequently the road remained unused, maintenance was neglected, and it now is to be closed. Here again the county authorities evidenced a great interest in planning. The development of an equitable and systematic county road plan acceptable to all offered an opportunity to eliminate the practice of undertaking unworthy projects such as this one.

A third county highway planning meeting was held for final adoption of the plan. This meeting was attended by all persons and groups within the county that were interested in highways. These included representatives from the chambers of commerce, civic clubs, and service organizations. The State highway advisory board member for the district was in attendance, as were State legislators representing Delta County. At this

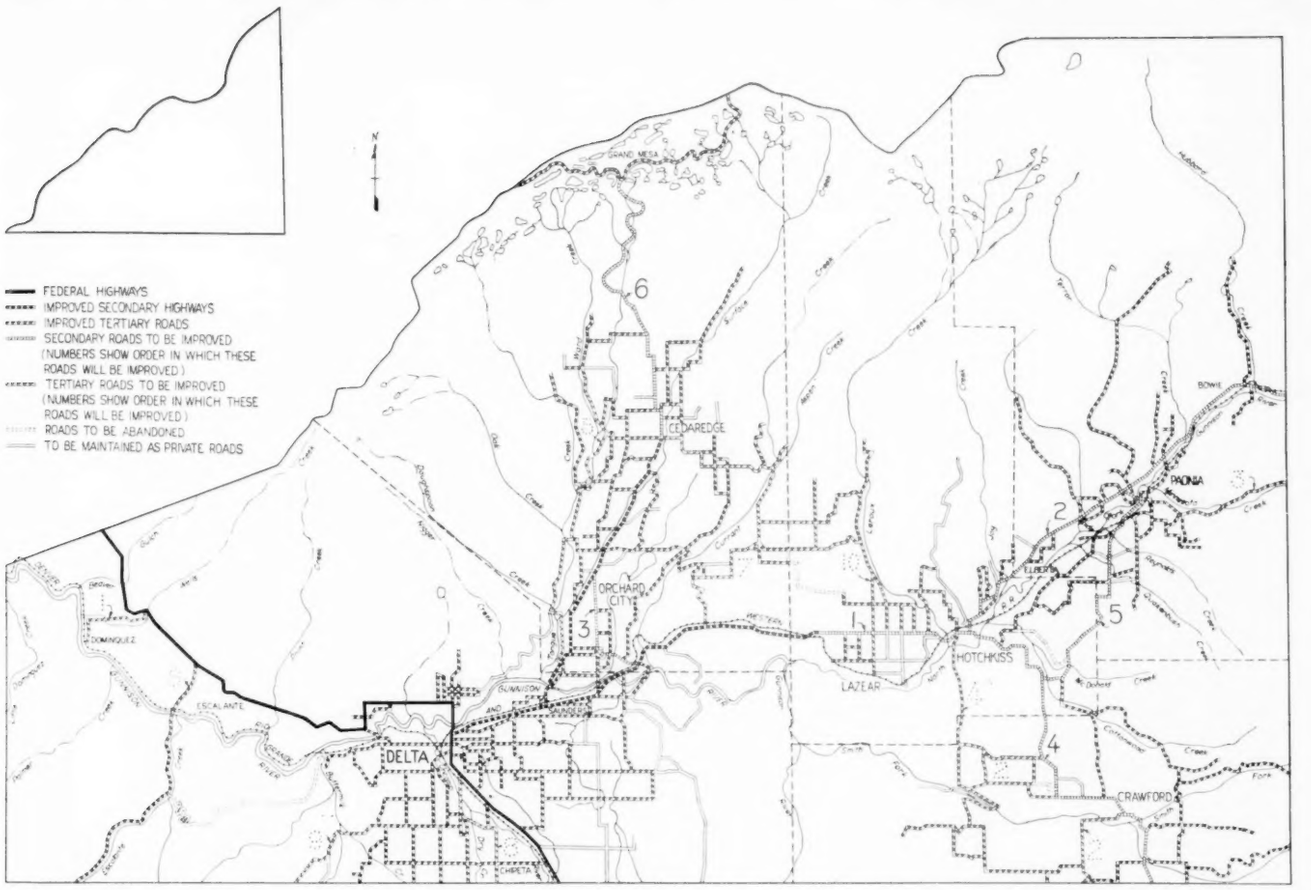

FIGURE 4.—PROPOSED RECLASSIFICATION OF ROADS INTO PUBLIC AND PRIVATE ROADS AND THOSE RECOMMENDED FOR ABANDONMENT, AND PROGRAM FOR ROAD DEVELOPMENT.

meeting all differences of opinion were aired and a system of roads finally adopted.

Each road was considered and, for each administrative system, priorities for construction were indicated on the map (fig. 4). It will be noted that the Federal-aid route (from Montrose through Delta to Grand Junction) is given no priority rating, because the local people are of the opinion that the present improvement is satisfactory and adequate for existing and anticipated traffic.

The Federal-aid secondary system as proposed is indicated by two symbols. One symbol shows portions considered satisfactory, while those portions which, in the opinion of the local people, require attention are shown by a different symbol. These latter sections are numbered from 1 to 6 in order of priority for improvement.

The county road system is also shown by two symbols; one indicating roads in satisfactory condition, the other indicating roads to be improved, again by priorities 1 to 10.

MANY MILES OF ROADS REMOVED FROM PUBLIC SUPPORT

Roads to be abandoned are shown by still another symbol. The remaining roads are considered private roads or ways of convenience, and were made the responsibility of abutting property owners or those individuals served; that is, they are no longer considered public roads. Roads in this classification are now being vacated by resolution. Thus, all road building agencies are now supplied with a long-range highway plan for the county. All interested groups and communities are united in a plan for improvement, and as funds become available, these funds can be expended to the best interests of the county as a whole.

With this plan, all of the road-building agencies will be in a position to work together on a united program of improvement which will take into consideration the needs of every county and every part of each county. The State highway advisory board member is conversant with the wishes of the county and will be able to advance Delta County's interests intelligently at the highway department budget meetings. The same holds true in programming Federal and county funds for the county.

The road system adopted as the result of these meetings and the advantages to the county are shown in table 2 and in the following recapitulation:

	Miles
Federal-aid system	24. 9
State system	81. 5
County system	433. 1
Total	539. 5
Roads abandoned	18. 6
Roads reverting to private ownership	278. 7
Total roads to be vacated	297. 3

The county has thus been relieved of responsibility for road construction and maintenance on 297.3 miles or approximately 36 percent of the road system (compare with table 1). Prior to the adoption of this plan,

TABLE 2.—*Delta County rural road mileages under land-use plan*

Condition	Federal-aid system	State system	County system	Total
	Miles	*Miles*	*Miles*	*Miles*
Unimproved			202.2	202.2
Graded and drained		28.6	106.3	134.9
Gravel		47.7	118.1	165.8
Low-type bituminous	24.9	5.2	6.5	36.6
Total	24.9	81.5	433.1	539.5

the county was attempting to service 132.4 miles of State highways (now reduced to 81.5 miles by dropping 50.9 miles) and 679.5 miles of county roads—a total of 811.9 miles—with a road and bridge fund of approximately $115,000 annually.

It would be well to point out that in Colorado the State highway laws provide that the State highway department can expend construction funds only on the State highway system, of which the Federal-aid system is a part. State highway maintenance funds can be spent only on the Federal-aid system.

During these several meetings all present were repeatedly informed and were made fully aware that completion of the program cannot be anticipated in 1 year, 5 years, or even 10 years. They are aware that situations may develop which will perhaps require modifications of the plan, yet it is a definite plan started from the grass roots. It is an intelligent plan accepted by the several road construction and maintenance agencies and consequently has a good chance to be carried to completion as the various highway funds become available.

No complete figures have as yet been obtained from the county as to the number of miles of road abandoned and petitioned for closing, as this work is still under way. It can be anticipated that many miles of private road will be closed.

A good example is in an eastern Colorado county which has progressed in this work to a point where results are now available. This county had 3,200 miles of highway prior to the time its highway planning program was set up. After proceeding along the lines already described, it was able to close 969 miles of dedicated county road without seriously affecting a single farmer or rancher. A total of 1,200 miles have been taken off the county road system by petition. These roads have reverted to private ownership, thus relieving the county of that construction and maintenance expense. The local authorities have realized their finances were limited, and with a county highway system confined to essential routes, intelligently and efficiently selected, these limited funds can be expended to provide an adequate well-improved road system which will meet the entire county road requirements.

The Delta County Planning Committee, realizing the vital need for wise and efficient administration of road funds, is now educating its people to plan for the future, and its excellent work in highway planning shows intelligent application of simple planning principles applied by unselfish interests.

Delta County is going further, as have several other counties in the State. A systematic review is being made of all school-bus and mail routes. Working with the board of education, school busses are being rerouted for more efficient service. One county in eastern Colorado has accomplished this, and reports a saving in contracts for student haul in the last six months of 1940, which enabled it to purchase a new school bus to replace an obsolete model. Likewise, working with postal authorities, mail routes have been changed to provide more economical service and prompter mail deliveries.

Admittedly, selfish interests must be overcome. Were the State or the Federal governments to attempt to reroute school busses or mail delivery, the local people would no doubt protest. Yet these same local people are now accomplishing this economy, requiring their children, in some instances, to walk half a mile to the bus line, or perhaps themselves walking some distance to their rural free delivery mail box. The school bus and the mail carrier no longer come up to their very front door.

OTHER PLANNING WORK BEING DONE

Other outgrowths of the local land-use meetings have been both surprising and encouraging. The subject of roadside development is an example. The State and Federal highway organizations, of course, are interested in this work. Limited amounts of funds have been expended during the past few years on this type of work. The landscaped areas adjacent to the highways in various parts of the State have, however, been all too few. Lack of moisture in most parts of Colorado precludes extensive landscape development because of prohibitive maintenance costs. However, there are many quick-growing shrubs and trees that are indigenous to the State and can be used for roadside development and parking areas.

In many communities, the women members of the county and community land-use planning groups have become interested in the creation of such areas. The State highway department has a landscape engineer who will cooperate with the county groups to create such areas and assist in solving problems. The State Forester has available thousands of trees suitable to the locality and will gladly supply them at a nominal price—in some instances as low as 15 cents per tree. The women are planning to develop some of these areas this year. The local property owners are contributing small strips of land to permit adequate turn-out facilities and the highway department of the State or county is contributing the necessary grading and approaches. The local groups are completing the planting and arranging for maintenance as a matter of civic pride. Larger projects of this kind should be undertaken at logical places, and as State and Federal funds become available these projects can be set up by the State.

It would seem proper to review briefly other commendable planning work done in Delta County. Certain problems have arisen regarding soil erosion. Here again the communities have mapped these respective areas, spotting critical erosion areas (see fig. 5) where the local people feel they have insufficient means to control the damage and prevent further destruction of the soil. This map also displays problem areas where low soil fertility is causing serious difficulty. The Soil Conservation Service and State College are now engaged in remedial measures to assist the local people in solving this problem.

Figure 6 displays water shortage problem areas. Here again the affected farmers and ranchers are working with the proper action agencies and the advice and experience of government technicians are helping to solve the problem.

Figure 7 displays the excessive seepage areas and areas where there is a shortage of water for domestic

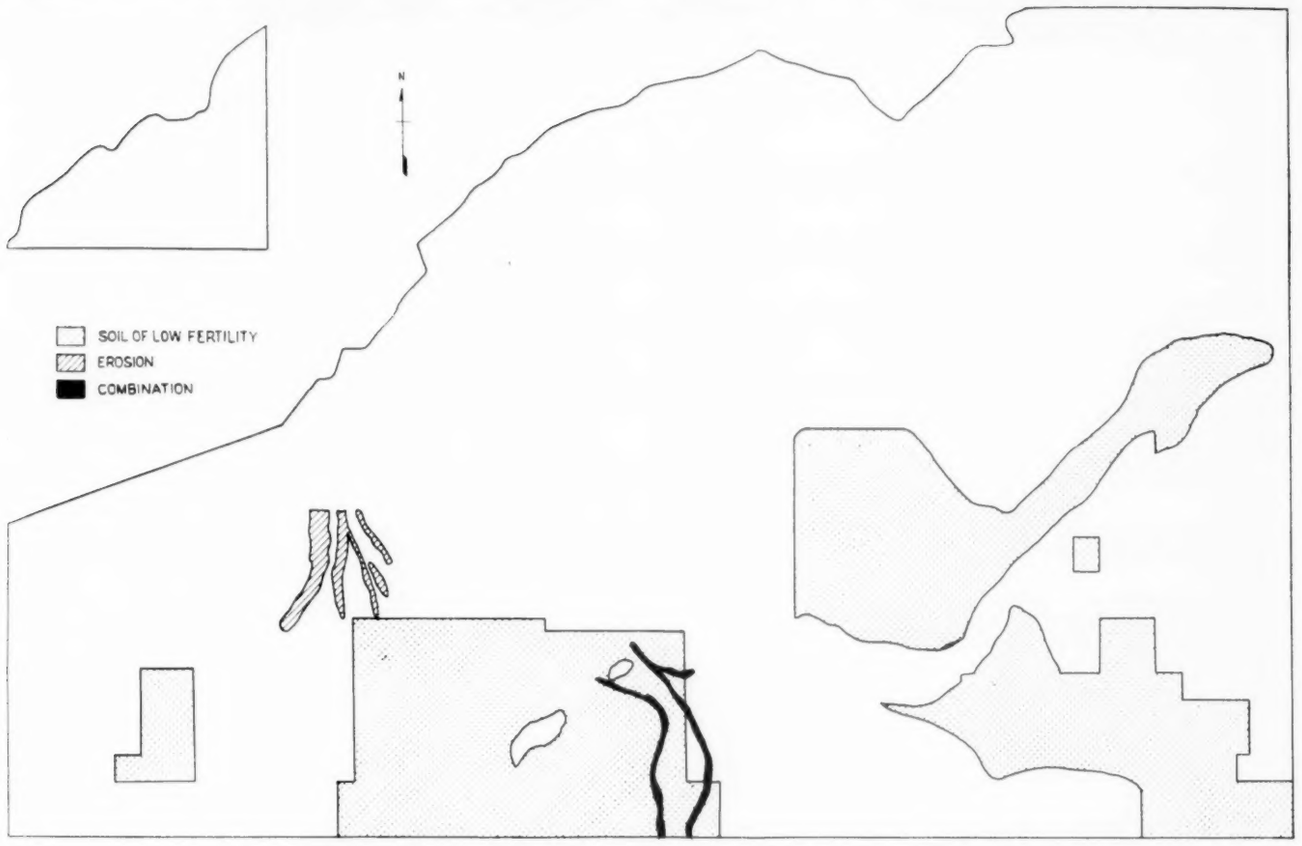

FIGURE 5.—AREAS HAVING LOW FERTILITY AND EROSION PROBLEMS.

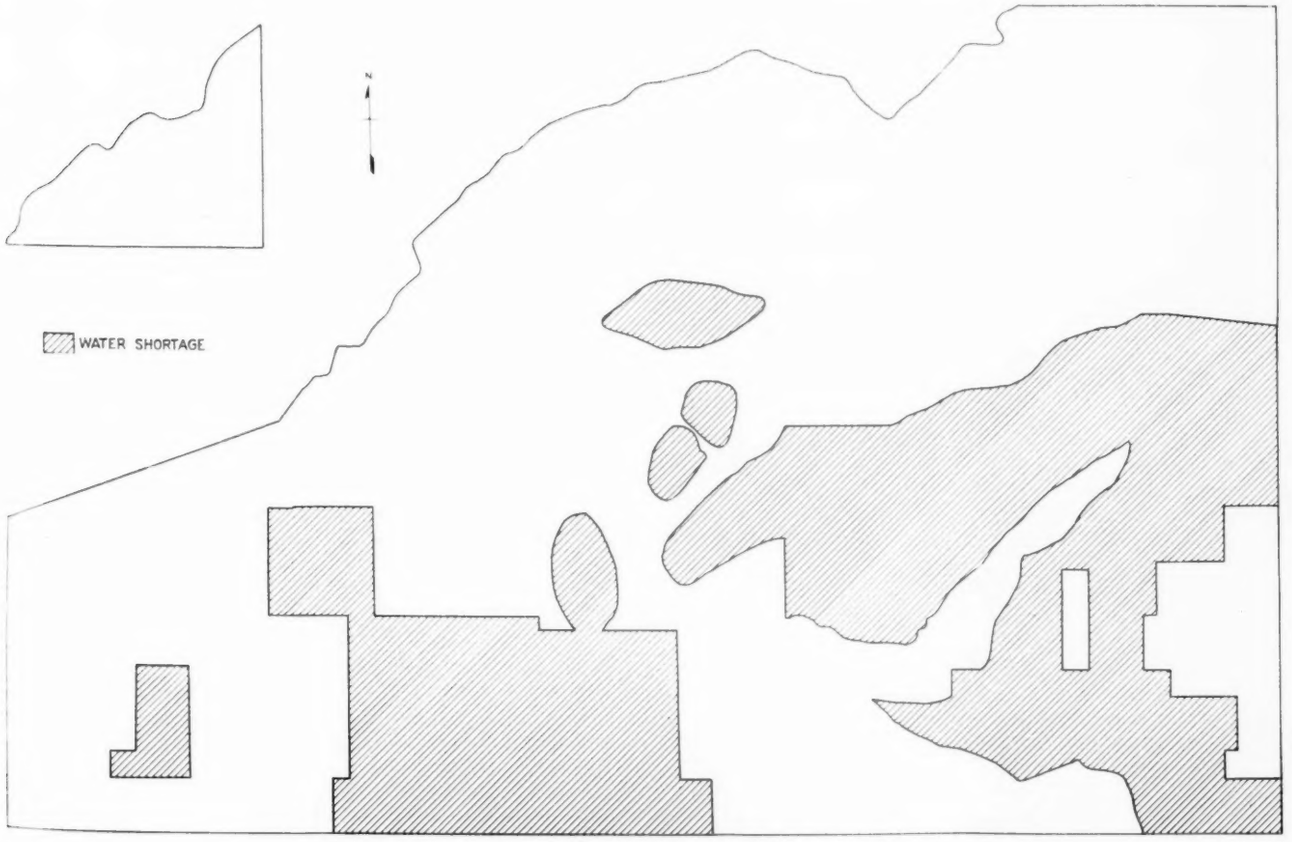

FIGURE 6.—WATER SHORTAGE AREAS.

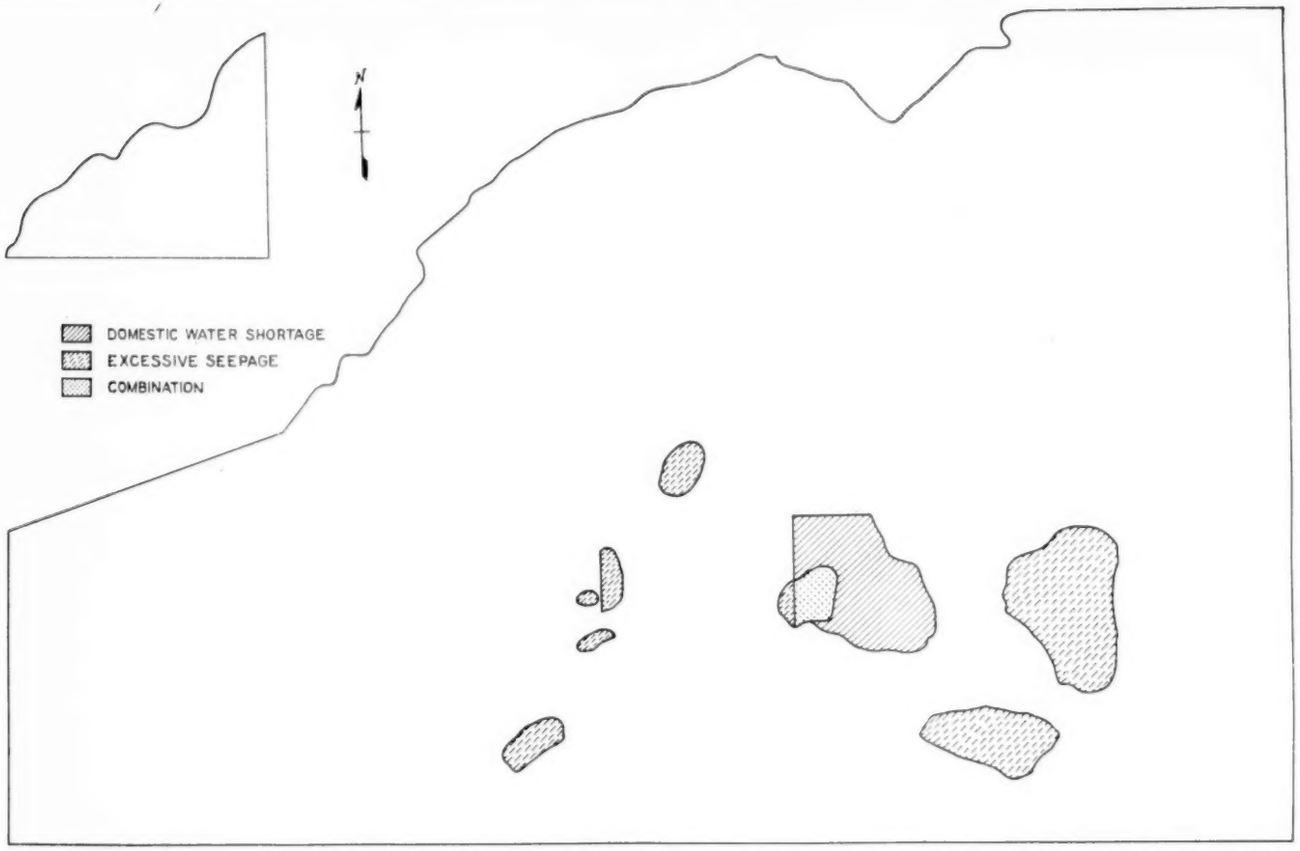

FIGURE 7.—AREAS WHERE THERE IS A SHORTAGE OF DOMESTIC WATER, AND AREAS OF EXCESSIVE SEEPAGE.

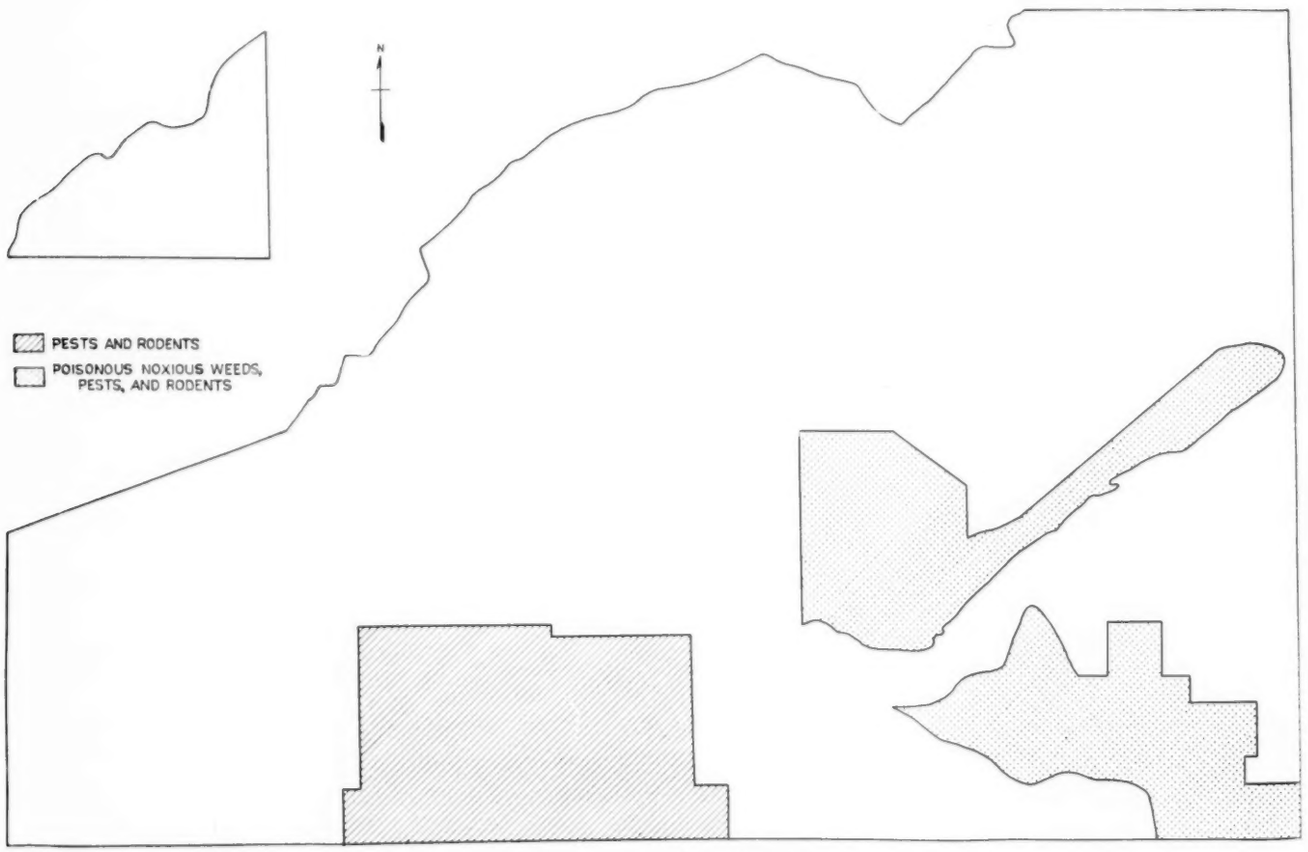

FIGURE 8.—PEST AND WEED PROBLEM AREAS.

use. The several State and Federal agencies are contributing time and funds to remedy this situation.

Figure 8 shows the pest and weed problem areas in the county and here progress is being made toward solving the problem through asistance given by the Biological Survey and other interested agencies.

It can be seen that all of the work accomplished by Delta County in land-use planning requires time and coordinated effort. Those counties that have undertaken this task are to be complimented. At this time many of the Colorado counties are in some stage of the work, and by the end of 1941 over a third of the 63 counties will have undertaken plans for a long-range program similar to that of Delta County.

In conclusion, it would be well to stress the vital need for coordination of effort. The State Agricultural Planning Committee is encouraging constructive planning for the coordination of activities within the State, and the country groups should place themselves behind this movement and stress the need for continuous efforts in highway planning. Expenditures for highways into submarginal areas should be discouraged. Planning for highways must insure efficient operation of a system of highways that meets the best interests of the individual county, the State, and the Nation.

(*Continued from p. 4.*)

In dealing with runoff problems it may be helpful to review briefly the physical phenomena which take place. To begin with, rain never falls at a uniform rate for long intervals. Rain falling at low intensities may be completely soaked up in the soil, this infiltration taking place rapidly at first and then at a minimum sustained rate regardless of how long rain may continue to fall. This infiltration rate depends on the size and compaction of soil particles, presence of organic material in the soil and on the surface (in the form of vegetation or mulches), and other factors. Rain falling on bare soil beats the soil into a muddy suspension which tends to clog the surface pores, thus decreasing infiltration. A mulch protects the soil from this action.

During the time that the rate of rainfall exceeds the rate of infiltration, runoff takes place. The small depressions fill up first and overflow until finally a sheet of water of appreciable depth is creeping slowly over the surface. From that point on the rapidity with which the water concentrates depends upon the number and kind of collecting channels.

Since a smoothly paved surface permits little or no infiltration, and offers little resistance to flow, the volume of water detained on the surface at any time is very small and the peak rate of runoff is very nearly equal to the peak rate of rainfall. On the other hand, a gently sloping bluegrass pasture has a high rate of infiltration, affords much resistance to surface flow, and can store up a large volume of water with the result that the peak rate of runoff may be only one-tenth the peak rate of rainfall. The stored-up water will flow out gradually over a long period of time, perhaps an hour or two after rainfall has ceased.

The frequency with which any peak rate of rainfall occurs in a given region can be determined from intensity–frequency data such as are contained in United States Department of Agriculture Miscellaneous Publication No. 204. A given intensity of rainfall will seldom produce the same peak rate of runoff in successive occurrences because the characteristics of the drainage area affecting runoff will vary within a wide range. Consequently a 2- or 5-year rainfall frequency may be safely used as equivalent to a longer runoff frequency. In attempting to evaluate the damage that may be done by runoff rates exceeding that for which a channel has been designed, it may be noted that on a given drainage area, the higher the peak rate the shorter the duration of that rate. The principal effect is to superimpose a sharper and higher peak on the runoff curve. The greater the opportunity for temporary surface storage, the less this peak will exceed the normal peak.

METHOD OF DESIGNING ROADSIDE CHANNELS SUGGESTED

Due to the uncertainties necessarily involved in estimating runoff from small drainage areas the simple calculations should not be carried out to more than one or two significant figures. Drainage area divides may be spotted by field parties taking preliminary cross sections, and plotted on a drainage area map preferably drawn to a fairly large scale. The estimation of runoff coefficients or the selection of runoff curves should not be done in the office by a draftsman, but should be done in the field by an engineer familiar with factors influencing runoff and able to visualize conditions likely to exist after construction is completed.

After peak rates of runoff have been estimated, a diagram of the type shown in figure 1 may be used to check the velocity developed in, and capacity of, the standard channel section ordinarily used. In the great majority of cases the capacity of the standard section will be found adequate. In a few cases the computed velocity will indicate the need for sodding. Infrequently, critical conditions will necessitate special study to develop economical designs.

The purpose of introducing this method of analysis is not to disrupt procedures of preparing plans developed through long years of experience but to add a simple check on channel design which will reveal, during the planning stage, the points at which extra care should be taken to avoid future difficulty and expense in maintaining the completed highway.

Detailed discussion of the construction and maintenance of vegetated channels is beyond the scope of this paper, but a few points should be noted. The kind of grass selected for seeding or sodding a channel should preferably be a short-bladed variety with a deep root system forming a dense turf and not a bunch grass around which the water will wash, or a stiff-stemmed grass which will not bend flat under the pressure of the current. The efficacy of sod for controlling erosion results largely from the "shingling" or "thatching" action which protects the soil from the rapidly flowing water in the stream. A favorable circumstance is the fact that in most regions the highest intensity rains, which cause the most erosion damage, normally occur during the summer months and not when the grasses are dormant. Experiments with bermuda grass, however, indicate that its resistance to erosion is practically as good when the grass is dormant as when it is green.

When seeding can be done at the right season of the year to establish a reasonably good turf in a short period of time, channels from very small drainage areas may be seeded instead of sodded, taking the chance that a damaging rain will not occur during that period. Any necessary reseeding will probably still involve less total cost than an initial installation of sod. Mulching of the seeded areas, now rather common practice, greatly decreases the chances of damage by intense

rains. Local circumstances and individual judgment will determine the extent to which chances may be taken on seeding in drainage channels.

In some regions grass is normally established by sprigging or planting stolons and roots, relying on the natural spreading habit of the particular species to establish complete cover in a short period of time. In such regions the remarks about seeding will apply with equal significance to these other inexpensive methods of establishing grass.

A compromise solution is to sod only the bottom of the channel, (assuming the bottom to be rounded) on the chance that a rate of runoff sufficient to rise above the sodded area will not occur until grass has become established by other, cheaper methods on the rest of the channel. To play safe, however, sod should be placed to an elevation slightly above the depth of the peak discharge for which the channel is designed (this procedure is recommended where sod is plentiful and relatively inexpensive).

Vegetated channels can function satisfactorily only if they are adequately maintained. Channels should be mowed regularly to avoid excessive restriction to flow and to keep down weeds. Bare spots should be repaired by sodding immediately upon discovery, as small breaks in the sod enlarge rapidly when subjected to heavy flows. Silting of the channel is a troublesome problem that can be permanently solved only by tracing the silt back to its source and eliminating erosion at that point. Since silt is deposited only when the carrying capacity of the stream is reduced by checking the velocity, channels should be designed, insofar as practical, so that the gradient is always increased, and never flattened, in the direction of flow.

HIGHWAY COST AND TAXATION STUDY PUBLISHED

"Analysis of Highway Costs and Highway Taxation With Application to Story County, Iowa," has recently been published as Iowa Engineering Experiment Station Bulletin No. 152.

This bulletin, by Dr. E. D. Allen, research economist of the Iowa Engineering Experiment Station, is a study of highway costs and taxation. The several general theories of highway finance are discussed at length, and the four current interpretations of highway costs are examined. Finally, highway costs and finances in Story County during the period 1913–38 are analyzed.

Single copies of the 128-page bulletin may be obtained without charge from the Iowa Engineering Experiment Station, Iowa State College, Ames, Iowa.

ESTIMATED MOTOR-FUEL USAGE AND MOTOR-VEHICLE REGISTRATION IN 1941

State	Motor-fuel usage				Motor-vehicle registration	
	Total, 1941	Total use in 1940	Increase, 1941 over 1940		Total, 1941	Increase over 1940
			Amount	Percentage		
	1,000 gallons	*1,000 gallons*	*1,000 gallons*			
Alabama	315,155	263,861	51,294	19.44	383,500	43,647
Arizona	127,484	111,516	15,968	14.32	145,150	6,747
Arkansas	219,707	189,811	29,896	15.75	289,550	32,373
California	2,181,979	1,948,880	233,099	11.96	2,995,000	221,341
Colorado	261,762	246,918	14,844	6.01	367,400	15,280
Connecticut	425,258	380,001	45,257	11.91	551,300	57,633
Delaware	67,554	62,800	4,754	7.57	80,200	8,437
Florida	478,670	405,415	73,255	18.07	557,850	62,640
Georgia	450,973	397,987	52,986	13.31	561,950	59,347
Idaho	117,384	107,644	9,740	9.05	171,000	7,660
Illinois	1,704,892	1,547,958	156,934	10.14	2,060,400	134,586
Indiana	800,612	700,360	100,252	14.31	1,070,400	76,394
Iowa	617,993	578,061	39,932	6.91	825,100	31,131
Kansas	527,516	493,514	34,002	6.89	617,350	34,682
Kentucky	350,019	301,902	48,117	15.94	499,350	35,623
Louisiana	315,743	269,916	45,827	16.98	438,800	73,371
Maine	172,246	157,361	14,885	9.46	224,250	18,354
Maryland	358,879	312,745	46,134	14.75	496,500	51,968
Massachusetts	807,152	744,903	62,249	8.36	965,300	61,457
Michigan	1,361,682	1,223,811	137,871	11.27	1,598,350	45,789
Minnesota	626,428	576,401	50,027	8.68	911,600	40,249
Mississippi	244,545	210,349	34,196	16.26	303,750	44,737
Missouri	770,946	703,256	67,690	9.63	984,450	62,650
Montana	147,077	134,974	12,103	8.97	198,550	7,518
Nebraska	252,432	236,852	15,580	6.58	417,300	5,184
Nevada	48,526	42,487	6,039	14.21	48,200	4,092
New Hampshire	102,972	95,827	7,145	7.46	141,800	6,416
New Jersey	1,007,621	923,490	84,131	9.11	1,173,150	86,184
New Mexico	118,845	108,834	10,011	9.20	130,500	5,444
New York	2,061,581	1,970,354	91,227	4.63	2,873,450	130,436
North Carolina	541,106	459,025	82,081	17.88	653,500	61,554
North Dakota	155,839	146,215	9,624	6.58	192,950	10,663
Ohio	1,584,236	1,430,533	153,703	10.74	1,972,250	53,321
Oklahoma	470,054	440,591	29,463	6.69	592,500	17,781
Oregon	302,028	264,654	37,374	14.12	430,450	36,872
Pennsylvania	1,713,174	1,581,975	131,199	8.29	2,307,600	161,751
Rhode Island	146,915	133,758	13,157	9.84	200,750	13,241
South Carolina	279,850	234,307	45,543	19.44	391,750	54,978
South Dakota	153,563	145,480	8,083	5.56	203,400	7,733
Tennessee	380,036	323,966	56,070	17.31	512,550	64,567
Texas	1,575,064	1,407,394	167,670	11.91	1,816,900	122,787
Utah	116,158	105,635	10,523	9.96	150,600	10,679
Vermont	75,576	70,806	4,770	6.74	97,650	4,005
Virginia	504,639	424,430	80,209	18.90	571,950	73,112
Washington	430,264	384,359	45,905	11.94	616,350	53,855
West Virginia	246,928	222,210	24,718	11.12	336,700	34,142
Wisconsin	619,584	575,119	44,465	7.73	957,900	56,985
Wyoming	80,242	70,753	9,489	13.41	91,150	5,493
Dist. of Columbia	194,503	169,127	25,376	15.00	176,750	14,836
Total	26,613,392	24,038,525	2,574,867	10.71	34,355,100	2,329,735

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF FEBRUARY 28, 1942

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$6,456,558	$3,207,060	228.2	$4,012,834	$1,991,205	115.2	$415,400	$206,050	0.3	$2,765,761
Arizona	1,535,097	1,073,116	65.6	1,286,108	916,511	43.1	384,302	254,599	8.4	2,050,364
Arkansas	3,633,486	1,666,991	57.4	1,173,174	585,470	60.1	66,680	33,340	.1	1,786,711
California	8,073,437	4,334,333	138.0	5,895,451	3,504,578	67.5	472,203	307,723	14.3	4,770,191
Colorado	2,323,253	1,290,718	154.6	3,508,479	2,067,537	155.6	919,347	512,943	35.4	2,516,033
Connecticut	1,419,554	696,181	17.1	1,715,156	821,787	18.4	481,485	239,471	9.4	1,228,870
Delaware	610,532	299,944	17.1	441,010	216,559	9.0	268,040	134,020	8.4	1,496,599
Florida	1,167,179	582,930	65.3	3,254,154	1,820,890	50.7	512,242	293,621	4.6	3,080,497
Georgia	2,994,295	1,495,854	111.4	7,235,800	3,627,650	272.4	3,078,525	1,539,263	131.7	7,032,315
Idaho	1,791,533	1,172,887	93.7	1,302,194	929,085	63.1	58,224	36,000	.1	1,981,206
Illinois	4,119,631	2,038,666	89.7	7,033,216	3,516,036	121.7	1,361,200	680,600	6.2	7,131,471
Indiana	4,528,531	2,096,487	74.4	5,302,939	2,572,704	75.6	2,191,200	1,095,600	32.7	2,869,329
Iowa	3,928,203	1,887,687	170.6	4,260,316	1,752,582	125.6	581,933	97,150	17.7	2,533,496
Kansas	4,625,910	2,354,279	260.1	5,260,573	2,631,145	239.1	1,914,950	1,052,838	65.3	4,807,666
Kentucky	3,756,759	1,853,568	138.6	6,465,362	3,091,041	127.2	2,004,624	935,397	15.1	2,012,929
Louisiana	1,031,219	521,393	24.2	1,820,379	1,140,826	37.8	2,553,917	1,251,767	56.3	4,304,975
Maine	953,093	469,404	26.8	2,070,392	1,061,696	27.8	78,610	39,305	.1	1,125,422
Maryland	2,765,267	1,381,529	29.6	3,446,909	1,466,154	15.0	35,000	17,500		1,587,207
Massachusetts	2,348,774	1,177,018	17.3	2,228,103	1,147,862	14.9	1,276,508	660,427	9.1	3,829,121
Michigan	8,422,298	4,109,603	174.2	2,919,748	1,547,374	50.6	886,300	452,325	9.3	3,847,750
Minnesota	4,484,865	2,207,751	378.0	9,504,473	4,708,665	388.4	368,018	184,009	20.1	3,497,493
Mississippi	5,332,567	2,602,918	283.3	3,723,624	1,864,462	218.1	42,100	24,000		2,306,444
Missouri	5,049,795	2,543,652	160.1	10,409,439	5,704,391	193.2	1,974,782	774,309	24.9	4,354,096
Montana	2,181,671	1,233,971	117.1	3,908,728	2,283,989	169.0	518,453	299,012	60.1	4,470,051
Nebraska	2,893,320	1,419,807	279.3	5,261,073	2,646,991	478.2	695,984	347,992	37.8	4,121,574
Nevada	2,235,406	1,914,788	110.6	742,339	643,031	22.0	274,686	238,701	3.4	1,417,147
New Hampshire	339,179	177,926	6.0	1,710,877	1,021,975	20.2				853,558
New Jersey	2,999,330	1,467,761	26.6	2,988,902	1,404,371	16.2				3,041,541
New Mexico	1,632,596	1,016,478	112.8	1,098,866	778,893	63.2				2,827,672
New York	9,605,419	4,820,744	126.7	7,910,755	5,051,640	80.6	1,083,700	633,400	12.8	5,184,248
North Carolina	3,947,309	2,083,865	162.0	2,943,504	1,597,189	123.7	901,030	473,585	23.4	3,500,407
North Dakota	3,218,183	1,828,431	287.6	2,566,572	1,368,670	203.7	2,448,925	1,236,615	205.5	4,187,226
Ohio	9,513,316	4,750,920	91.7	11,303,572	5,413,691	76.8	5,465,320	2,157,658	29.7	4,458,134
Oklahoma	2,423,158	1,223,371	112.7	2,450,022	1,292,789	46.7	1,873,280	979,830	66.1	6,271,954
Oregon	2,684,938	1,585,246	72.9	3,299,713	1,718,698	71.5	403,168	294,330	30.9	1,616,095
Pennsylvania	10,068,733	4,993,380	98.5	8,522,848	4,178,504	64.5	3,094,286	1,967,432	24.9	4,453,507
Rhode Island	1,196,941	596,510	10.0	644,776	322,368	4.8	644,448	322,224	2.0	940,591
South Carolina	2,027,604	932,297	87.3	3,945,029	2,377,067	90.0	959,119	547,497	26.7	1,594,094
South Dakota	2,218,282	1,294,086	266.9	4,812,831	3,179,872	544.1	644,800	381,560	69.6	2,868,727
Tennessee	3,884,513	2,046,955	105.3	4,835,864	2,907,905	92.6	500,230	297,672	15.2	3,539,138
Texas	9,975,401	4,873,055	505.9	12,578,570	5,998,706	415.2	2,298,400	936,410	79.2	9,509,149
Utah	1,206,946	907,446	53.8	1,761,015	1,325,602	41.3	87,256	65,634	5.3	1,286,573
Vermont	831,235	429,145	28.8	1,192,668	694,327	20.7	36,906	18,453	.3	434,096
Virginia	3,934,015	1,839,199	74.7	3,460,798	1,687,536	57.3	35,400	17,745	.4	2,941,214
Washington	1,612,928	838,027	25.7	2,671,742	1,429,754	31.4	43,686	23,400	1.0	2,246,300
West Virginia	2,778,324	1,380,071	51.4	2,482,738	1,231,611	29.3	338,900	166,750	1.8	2,199,155
Wisconsin	2,195,334	1,077,854	92.7	5,618,496	2,633,643	163.9	1,262,339	454,400	44.6	4,798,393
Wyoming	1,446,636	912,464	148.3	1,773,023	1,317,527	123.5	34,714	22,321	.1	1,365,245
District of Columbia	578,415	285,730	3.3	721,662	396,682	1.1	600,000	382,500	.2	314,642
Hawaii	133,296	66,648	2.8	1,285,460	720,206	10.9	180,504	161,032	3.5	1,844,846
Puerto Rico	470,767	232,845	3.8	2,150,785	1,062,205	18.1	192,540	133,685	.2	724,111
TOTALS	169,589,138	87,293,589	5,840.5	198,779,061	105,461,652	5,570.6	46,631,754	23,392,095	1,214.2	155,985,334

STATUS OF FEDERAL-AID SECONDARY OR FEEDER ROAD PROJECTS

AS OF FEBRUARY 28, 1942

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$1,392,972	$695,108	62.5	$517,831	$281,500	25.2	$206,101	$96,530	6.0	$585,420
Arizona	245,110	174,247	14.1	15,183	13,767		126,598	61,439	6.8	548,054
Arkansas	610,518	233,221	33.1	348,210	174,039	26.3	135,644	67,822	.2	339,836
California	940,338	542,934	18.3	806,150	630,333	7.6				1,067,018
Colorado	157,106	82,891	20.7	129,755	72,650	2.1	199,327	61,919	6.3	505,877
Connecticut	298,035	136,331	6.1	266,247	115,938	4.8				199,604
Delaware	81,076	38,116		224,923	111,986	12.3	102,873	37,618	3.9	246,037
Florida	498,886	249,443	4.7	666,633	338,767	7.1	161,570	80,680	5.9	402,653
Georgia	545,666	257,833	43.4	1,143,478	664,089	71.6	461,092	230,996	47.0	1,125,176
Idaho	293,347	172,516	26.2	187,185	118,985	7.7	78,125	48,303	5.9	299,311
Illinois	1,073,034	518,949	59.4	1,147,660	573,830	54.5	96,500	48,250	10.6	903,371
Indiana	600,171	295,687	39.8	1,128,455	531,071	46.7	189,600	94,800	6.4	936,690
Iowa	597,238	281,841	148.3	398,264	170,008	64.8	346,551	161,825	60.5	588,518
Kansas	773,140	387,620	98.3	1,650,915	830,957	98.6	460,565	230,282	36.9	1,039,033
Kentucky	1,161,015	321,329	83.2	1,267,862	388,683	37.2	74,213	24,400	5.6	353,316
Louisiana	571,169	233,519	20.6	7,700	3,850		289,362	138,761	21.5	698,808
Maine	77,540	38,770	3.6	235,218	117,609	10.5	16,850	2,714	.4	161,104
Maryland	473,000	236,500	19.5	333,376	166,513	3.1				345,564
Massachusetts	179,789	93,569	4.1	663,234	352,683	10.1				572,305
Michigan	1,218,371	600,611	76.3	780,498	390,249	24.8	315,969	157,985	11.2	641,630
Minnesota	1,598,379	799,373	217.1	973,917	484,107	86.9	302,776	149,988	30.1	605,414
Mississippi	829,715	414,858	46.5	1,199,746	533,738	47.6	274,300	137,150	11.5	436,055
Missouri	434,916	215,032	52.9	868,872	416,848	89.5	234,254	87,198	36.9	1,053,224
Montana	377,420	214,407	58.5	292,724	170,722	31.0	13,569	7,715	4.5	889,999
Nebraska	359,864	179,301	49.4	487,813	248,520	64.7	31,940	15,970	9.2	684,152
Nevada	224,109	185,777	24.1	92,413	60,816	4.6	99,973	79,290	4.5	235,306
New Hampshire	152,914	75,436	4.7	241,629	119,915	3.6				152,254
New Jersey	497,637	244,471	9.6	412,615	230,410	12.1	51,500	25,750	1.8	570,561
New Mexico	566,935	357,245	47.7	189,504	122,533	15.2				296,856
New York	959,667	469,941	28.8	894,946	488,111	14.3	485,666	242,833	1.5	1,095,984
North Carolina	339,731	177,102	34.9	529,507	285,848	36.3	69,820	20,000	5.0	681,541
North Dakota	29,802	15,664	2.4	7,382	7,382		808,050	793,860	42.7	755,172
Ohio	1,777,334	886,683	57.6	883,130	489,535	14.5	71,000	35,500	2.0	1,388,480
Oklahoma	363,550	191,497	21.6	64,572	34,093	9.9	903,706	477,157	64.1	1,083,038
Oregon	463,659	243,290	41.8	459,611	217,324	28.5	30,482	18,000	1.3	405,495
Pennsylvania	1,727,496	863,074	32.0	780,163	379,689	16.0	73,583	36,794	1.8	777,528
Rhode Island	220,879	111,427	2.6	22,194	18,197					130,911
South Carolina	787,356	307,866	54.6	221,700	79,945	.5				397,720
South Dakota	33,337	18,686	15.2	7,778	7,778		1,143,430	1,047,600	114.5	761,862
Tennessee	468,207	232,400	14.1	1,337,954	668,977	46.0	158,042	79,021	4.5	770,269
Texas	1,314,680	634,272	132.4	711,479	347,847	62.8	43,500	21,700	4.8	2,253,336
Utah	186,949	123,241	17.0	153,666	101,709	6.8				337,043
Vermont	40,708	18,109	1.2	180,204	85,595	7.8	42,311	31,733	1.1	53,580
Virginia	370,460	174,585	15.8	346,346	154,866	4.3	59,650	29,825	4.5	676,248
Washington	279,641	160,072	17.8	454,148	211,574	13.7				413,564
West Virginia	400,342	202,347	19.8	328,314	163,644	6.4				501,897
Wisconsin	936,706	467,669	42.7	1,406,919	646,743	46.0	64,461	31,320	.8	595,789
Wyoming	357,528	158,064	18.8	528,423	218,112	34.3				220,633
District of Columbia	76,620	37,756	.9	2,558	1,279					163,600
Hawaii				2,375	2,375					334,875
Puerto Rico	170,027	77,541	7.5	73,642	38,810	3.1				217,968
TOTALS	28,134,089	13,848,221	1,872.2	26,055,030	13,084,599	1,221.4	8,221,858	4,912,728	582.2	30,500,579

U. S. GOVERNMENT PRINTING OFFICE: 1942

PUBLICATIONS of the PUBLIC ROADS ADMINISTRATION

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. As his office is not connected with the Agency and as the Agency does not sell publications, please send no remittance to the Federal Works Agency.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1931. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1932. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1933. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1934. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1935. 5 cents.

Report of the Chief of the Bureau of Public Roads, 1936. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1937. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1938. 10 cents.

Report of the Chief of the Bureau of Public Roads, 1939. 10 cents.

Work of the Public Roads Administration, 1940.

HOUSE DOCUMENT NO. 462

Part 1 . . . Nonuniformity of State Motor-Vehicle Traffic Laws. 15 cents.

Part 2 . . . Skilled Investigation at the Scene of the Accident Needed to Develop Causes. 10 cents.

Part 3 . . . Inadequacy of State Motor-Vehicle Accident Reporting. 10 cents.

Part 4 . . . Official Inspection of Vehicles. 10 cents.

Part 5 . . . Case Histories of Fatal Highway Accidents. 10 cents.

Part 6 . . . The Accident-Prone Driver. 10 cents.

MISCELLANEOUS PUBLICATIONS

No. 76MP . . The Results of Physical Tests of Road-Building Rock. 25 cents.

No. 191MP. . Roadside Improvement. 10 cents.

No. 272MP. . Construction of Private Driveways. 10 cents.

No. 279MP. . Bibliography on Highway Lighting. 5 cents.

Highway Accidents. 10 cents.

The Taxation of Motor Vehicles in 1932. 35 cents.

Guides to Traffic Safety. 10 cents.

An Economic and Statistical Analysis of Highway-Construction Expenditures. 15 cents.

Highway Bond Calculations. 10 cents.

Transition Curves for Highways. 60 cents.

Highways of History. 25 cents.

Specifications for Construction of Roads and Bridges in National Forests and National Parks. 1 dollar.

DEPARTMENT BULLETINS

No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.

No. 1486D . . Highway Bridge Location. 15 cents.

TECHNICAL BULLETINS

No. 55T . . . Highway Bridge Surveys. 20 cents.

No. 265T. . . Electrical Equipment on Movable Bridges. 35 cents.

Single copies of the following publications may be obtained from the Public Roads Administration upon request. They cannot be purchased from the Superintendent of Documents.

MISCELLANEOUS PUBLICATIONS

No. 296MP. . Bibliography on Highway Safety.

House Document No. 272 . . . Toll Roads and Free Roads.

Indexes to PUBLIC ROADS, volumes 6–8 and 10–21, inclusive.

SEPARATE REPRINT FROM THE YEARBOOK

No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio (1927).

Report of a Survey of Transportation on the State Highways of Vermont (1927).

Report of a Survey of Transportation on the State Highways of New Hampshire (1927).

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio (1928).

Report of a Survey of Transportation on the State Highways of Pennsylvania (1928).

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States (1930).

UNIFORM VEHICLE CODE

Act I.—Uniform Motor Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.

Act II.—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III.—Uniform Motor Vehicle Civil Liability Act.

Act IV.—Uniform Motor Vehicle Safety Responsibility Act.

Act V.—Uniform Act Regulating Traffic on Highways.

Model Traffic Ordinances.

A complete list of the publications of the Public Roads Administration, classified according to subject and including the more important articles in PUBLIC ROADS, may be obtained upon request addressed to Public Roads Administration, Willard Bldg., Washington, D. C.

STATUS OF FEDERAL-AID GRADE CROSSING PROJECTS

AS OF FEBRUARY 28, 1942

STATE	COMPLETED DURING CURRENT FISCAL YEAR					UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FUNDS AVAILABLE FOR PROGRAMMED PROJECTS
			NUMBER					NUMBER					NUMBER			
	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Federal Aid	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$151,956	$151,436	2	4	2	$383,625	$381,603	5	2	2	$52,335	$52,335	2		5	$1,129,271
Arizona	184,378	184,361	1	1		125,274	116,583		1		13,255	13,255			2	234,779
Arkansas	464,676	463,371	5		5	166,996	165,286	1		1	22,858	22,858			7	683,334
California	833,918	644,346	2	1	4	870,516	868,399	8			12,450	12,450			4	2,319,005
Colorado	5,685	5,646				664,333	664,333	7			21,042	21,042			10	730,378
Connecticut	166,222	165,415	2			61,712	60,676		1		231,374	222,740		1		525,593
Delaware	89,725	89,725	1		1	191,599	189,867	1	1		508,406	301,785	2			179,564
Florida	120,961	120,961			20	733,446	731,266	8		6	187,620	187,560			14	875,288
Georgia	660,009	660,009	7	2	5	843,014	843,014	5	6	10	943,446	943,446	3	4	14	1,515,675
Idaho	25,827	21,580			2	328,273	313,602	4	1		6,212	6,212			3	427,671
Illinois	687,682	565,714	2		82	1,667,042	1,570,807	8	1	9	414,244	396,294	1	1	35	2,561,553
Indiana	606,392	594,413	6		20	464,035	458,326	2	1	21	96,164	96,164			23	1,174,656
Iowa	353,794	342,320	3	1	28	1,444,738	1,192,530	10	2	15	176,038	174,725			43	663,450
Kansas	67,313	66,808	2		6	679,768	679,768	8		1	212,835	208,304	4		10	1,316,576
Kentucky	1,111,122	1,108,759	3		1	441,711	441,711	4	1							410,133
Louisiana	6,965	6,965				586,220	586,220	8			481,835	480,667	4		4	923,884
Maine						363,086	363,086	2			8,680	8,680			3	288,623
Maryland	488,250	456,457	2	2	10	879,908	736,111	4		5	37,325	37,325			7	399,876
Massachusetts	346,270	335,829	1		1	774,431	773,559	5	2		763,830	763,830	2	1		1,267,765
Michigan	1,314,447	1,307,560	3	4	19	253,416	253,416	1		5	333,180	303,019	1		11	1,325,454
Minnesota	532,378	532,064	5	3	1	1,074,944	1,074,944	5	5	4	59,688	59,688		1	4	1,104,726
Mississippi	235,874	235,874	2	1	4	861,110	861,110	10		6	25,808	25,808			2	645,010
Missouri	120,702	120,702		2		1,922,921	1,467,501	6	2		464,353	464,353	2	2		1,489,049
Montana	141,549	141,549	2		2	93,778	93,778	1								733,051
Nebraska	200,886	200,495	2	1	22	1,142,413	1,142,413	21		1	13,020	13,020			3	451,612
Nevada	119,580	119,580	2			59,085	59,085	2		1	28,124	28,124			9	192,599
New Hampshire	261,080	260,783	4	1	2	100,861	100,536	2	1	3						313,952
New Jersey	845,837	844,536	4	1	1	629,879	504,329	3	1	1	364,085	295,560	1	2		930,833
New Mexico						68,342	68,342	1			259,103	252,068	3		1	521,824
New York	2,420,733	2,364,650	2	13		1,962,136	1,921,057	3	8		502,645	464,285		1		3,747,433
North Carolina	518,515	518,515	2	5	23	178,696	175,818		2	2	235,253	235,253	1	1	20	1,316,139
North Dakota	174,102	172,895	4			601,585	591,648	6			223,120	223,120	2			636,650
Ohio	1,544,019	1,528,804	3	1	6	2,767,792	2,444,070	10		2	405,140	401,010	1		7	1,697,332
Oklahoma	181,964	178,170	1		30	946,514	943,104	7		6	266,890	228,853	2		3	1,558,730
Oregon	419,536	355,855	4		3	203,552	187,715	2			2,733	2,733			2	442,391
Pennsylvania	1,675,339	1,675,011	13	1		3,238,872	3,187,962	15			359,074	359,074	2			2,542,633
Rhode Island	205,241	205,241		1		3,655	3,655									273,921
South Carolina	347,737	334,405	6		21	245,569	224,728	2	3	2	238,868	123,735	1	2	8	977,579
South Dakota	507,443	507,443	13		9	521,843	505,893	9			41,200	41,200	2			827,558
Tennessee	301,580	289,686	3	3		1,325,647	1,325,647	7	1		102,106	102,106		1	2	1,005,387
Texas	1,225,529	1,204,217	15			1,467,237	1,455,643	14		4	4,350	4,350			1	2,372,045
Utah	58,794	58,052	2		19	69,369	69,369	1		9	60,140	60,140			23	359,438
Vermont	18,683	18,671			4	322,869	293,090	2								103,978
Virginia	438,014	438,014	2	2	2	442,273	422,313	4	3	1	33,021	33,021	1		2	959,061
Washington	175,020	171,817	1	2	2	1,257,474	560,800	7		1	5,192	5,192			2	439,527
West Virginia	253,143	247,512	3		6	654,510	654,510	6	1	2	3,330	3,330			1	776,753
Wisconsin	480,777	451,749	2		39	568,623	567,635	3	2	6	15,484	15,484			3	1,673,330
Wyoming	483,177	466,619	5		1	1,974	1,974				8,416	8,416			6	429,924
District of Columbia	2,193	2,193				293,675	275,206		1							103,351
Hawaii	187,618	187,618	2			214,170	213,655	2								282,756
Puerto Rico	101,629	102,980	1			780,619	772,706	11								363,914
TOTALS	21,868,772	21,226,775	158	52	403	35,948,190	33,568,399	253	49	126	8,235,172	7,521,614	37	17	294	48,323,014